

NASA
Reference
Publication
1290

October 1993

NASA Trend Analysis Procedures

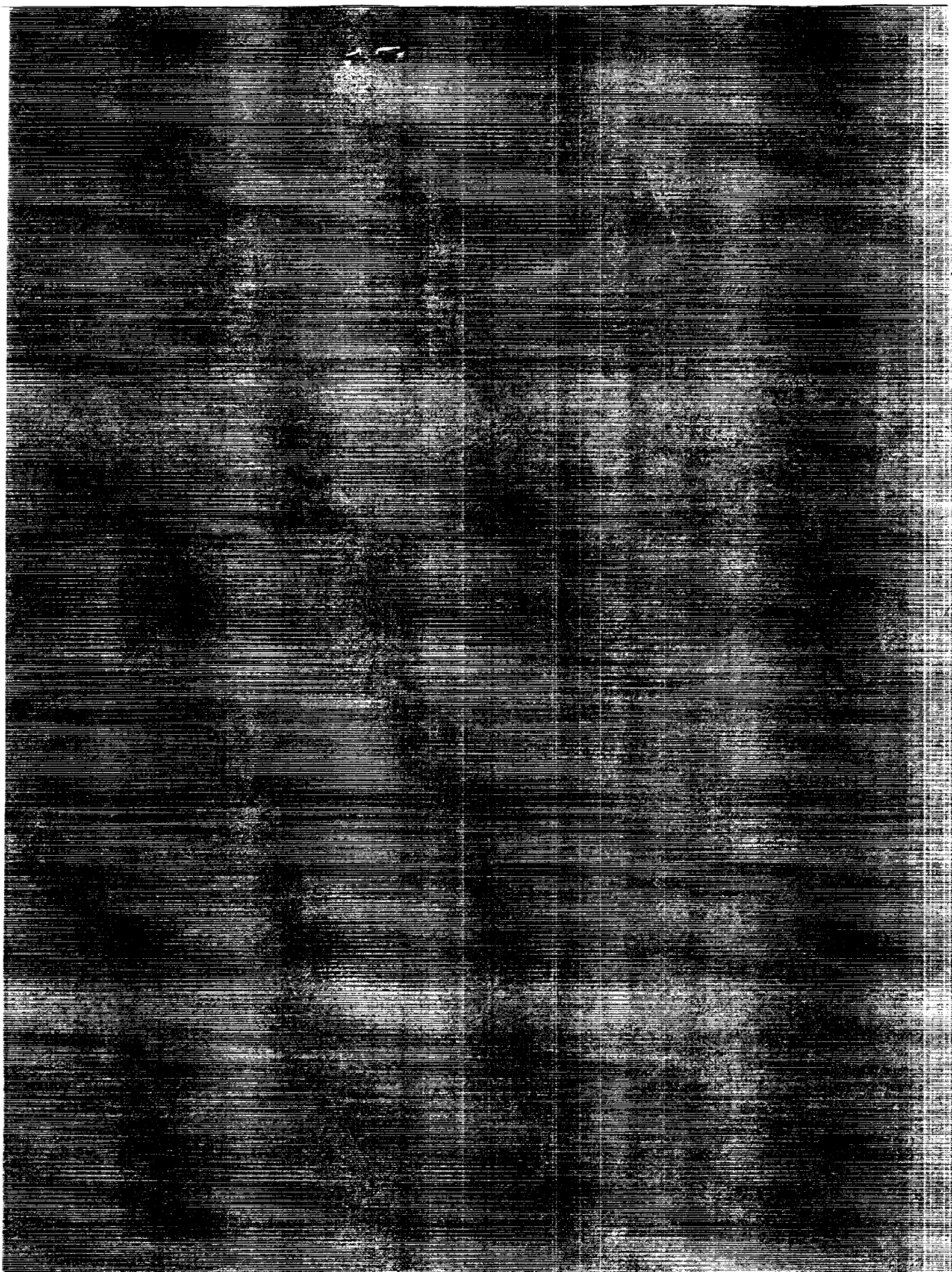
(NASA-RP-1290) NASA TREND ANALYSIS
PROCEDURES (NASA) 71 p

N94-15752

Unclass

H1/81 0190898

NASA



**NASA
Reference
Publication
1290**

1993

NASA Trend Analysis Procedures

NASA Trend Analysis Working Group
Safety and Risk Management Division
NASA Office of Safety and Mission Assurance
Washington, D.C.



National Aeronautics and
Space Administration

Office of Management

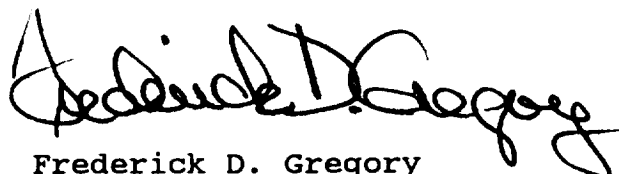
Scientific and Technical
Information Program

PREFACE**EFFECTIVE DATE: June 1993**

This reference publication, "NASA Trend Analysis Procedures," is a companion document to NMI 8070.3, "Problem Reporting, Corrective Action, and Trend Analysis Requirements." It is intended to provide uniform guidelines for conducting trend analyses for aeronautics and space programs. It is for the use of NASA Headquarters and NASA field installations involved in the development and operation of these programs.

Development of essential information on which NASA management can base critical risk-management decisions affecting safety and mission success is necessary for the continued credibility and success of this Nation's aeronautics and space programs. This document has been prepared to support this need and should be used in conjunction with the NASA 8070 series of directives.

General questions on this document should be referred to the Office of Safety and Mission Assurance (SMA), Director, Safety and Risk Management Division (Code QS), Washington, DC 20546. Questions concerning the application of these guidelines to specific programs or projects should be referred to the cognizant SRM&QA Director at the NASA field installation.



Frederick D. Gregory
Associate Administrator for
Safety and Mission Assurance

DISTRIBUTION:
SDL 1 (SIQ)

PRECEDING PAGE BLANK NOT FILMED

This page intentionally left blank.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

100	Purpose	1
101	Scope	1
102	Policy	1
103	Definitions	1
104	References	2

CHAPTER 2: GUIDELINES

200	Introduction	3
201	Basic Guidelines for Trend Analysis	3
202	Types of Trend Analysis	4
203	Performance Trend Analysis	4
204	Problem Trend Analysis	4
205	Supportability Trend Analysis	4
206	Programmatic Trend Analysis	4

APPENDIX A: Performance Trend Analysis

A100	Introduction	A-1
A200	Objective	A-1
A201	Applications	A-2
A300	Candidates	A-2
A301	Criticality (Based on FMEA/CIL Data)	A-2
A302	Availability/Trendability of Sensor Data	A-2
A303	Problem History	A-3
A400	Data Sources	A-4
A500	Considerations	A-4
A501	Indirect Parameter Indicators	A-4
A502	Complementary Performance Data	A-4
A503	Trend Limits Adjustment (based on operating history)	A-4
A504	Normalizing/Correction Factors	A-5
A505	Performance Measurements	A-5
A506	Data Sampling Rate	A-5
A507	Data Sampling Resolution	A-5
A508	Compression-effect on Resolution	A-6
A509	Data/System Stability	A-6
A510	Calibration	A-6
A600	Procedures	A-6
A700	Reporting	A-8
A701	Format	A-8
A702	Frequency	A-9

APPENDIX B: Problem Trend Analysis

B100	Introduction	B-1
B200	Objectives	B-1
B300	Candidates	B-1
B400	Data Sources	B-3
B500	Considerations	B-3
B501	Level of Problem Trend Analysis	B-4
B502	Engineering Judgement	B-4
B503	Statistical Analysis	B-5
B504	Conflict Between Engineering Judgement and Statistical Analysis	B-5
B505	Data Normalization	B-5
B506	Goodness-of-Fit	B-6
B507	Trend Direction	B-6
B508	Adverse and Favorable Trends	B-6
B600	Procedures	B-7
B601	Hierarchical Approach and the Five-Step Method	B-7
B602	<u>Step 1</u> : Research Data Base and Extract Data	B-8
B603	<u>Step 2</u> : Construct a Subsystem or Component-Level Normalized Trend Analysis Chart	B-9
B604	<u>Step 3</u> : Construct a Pareto Chart of Failure Modes/Causes and Identify Area(s) of Concern	B-10
B605	<u>Step 4</u> : Construct a Normalized Problem Trend Chart for Area(s) of Concern	B-11
B606	<u>Step 5</u> : Prepare Summary Assessment of Problem Trend Analysis with Recommendations	B-13
B700	Reporting	B-15
B701	Format	B-15
B702	Frequency	B-15
B703	Reporting Results	B-15
B704	Maintaining Problem Trend Analysis Status	B-16

APPENDIX C: Supportability Trend Analysis

C100	Introduction	C-1
C200	Objectives	C-1
C300	Candidates	C-2
C400	Data Sources	C-3
C500	Considerations	C-4
C501	Maintenance Concept	C-5
C502	System/Subsystem/Unit Selection Criteria	C-5
C503	Line Items/Spare Parts	C-5
C504	Indirect Parameter Indicators	C-5
C505	Complementary Data	C-5
C506	Trend Limits Adjustment Based on Operating History	C-6
C507	Normalizing/Correction Factors	C-6
C508	Data Delay	C-6
C509	Data Accuracy	C-6
C510	Corrective Action	C-6
C600	Procedures	C-7

C700	Reporting	C-8
C701	Format	C-8
C702	Basic Supportability Analyses	C-8
C703	Frequency	C-16

APPENDIX D: Programmatic Trend Analysis

D100	Introduction	D-1
D200	Objectives	D-1
D300	Candidates	D-2
D400	Data Sources	D-2
D500	Procedures	D-3
D501	Standard Data	D-3
D502	Parameters	D-3
D600	Reporting	D-4
D601	Format	D-4
D602	Frequency	D-7

APPENDIX E: Glossary of Terms

Glossary of Terms	E-1
-------------------	-----

APPENDIX F: List of Acronymns

List of Acronyms	F-1
------------------	-----

This page intentionally left blank.

CHAPTER 1: INTRODUCTION

100 PURPOSE

1. The purpose of trend analysis is to analyze past performance to provide information that can be used to assess current status and predict future performance.
2. The purpose of this reference publication is to establish a uniform, agencywide mechanism for providing NASA management with trend analysis data on which to base top-level decisions affecting the safety and success of developmental or operational space and aeronautical programs/projects and related payloads, and institutional support facilities.
3. This reference publication supplements policies and requirements of NMI 8070.3 by providing specific guidance for implementing trend analysis to support NASA programs. This publication also supplements NASA-STD-8070.5, which provides applicable mathematical/statistical techniques.

101 SCOPE

These guidelines support the objectives of the NASA Office of Safety and Mission Assurance (OSMA) and are applicable to all NASA organizational elements that support technology research and development (R&D), operational space programs/projects (including payloads), aeronautical programs, and all associated institutional support facilities.

102 POLICY

NASA policy for the performance and reporting of trend analysis is contained in NMI 8070.3. This publication provides guidance to assure the proper use of trend analysis to support Agency operational functions. Nothing in this document is intended to restrict innovation or application of trend analysis.

103 DEFINITIONS

Definitions of terms are provided in the Glossary of Terms, Appendix E.

104 REFERENCES

1. NMI 1103.39, "Role and Responsibilities--Associate Administrator for Safety and Mission Assurance (SMA)."
2. NMI 8070.3, "Problem Reporting, Corrective Action, and Trend Analysis Requirements."
3. NMI 8621.1, "Mishap Reporting and Investigating."
4. NHB 5300.4(1A-1), "Reliability Program Requirements for Aeronautical and Space System Contractors."
5. NASA-STD-8070.5, "Trend Analysis Techniques."
6. NASA Technical Memorandum 85840, "The Planning and Control of NASA Programs and Resources."

CHAPTER 2: GUIDELINES

200 INTRODUCTION

1. The major goal of each NASA program management level is to achieve operational and research objectives while ensuring that all NASA and NASA-sponsored flight, orbital, and ground operations are conducted safely and with a full understanding of mission risks. Achievement of this goal is supported through rigorous engineering analyses and assessments. The NASA system of trend analysis addresses the institutional characteristics and performance of each program as well as progress toward improving the program and eliminating problems.
2. Trend analysis is an element of engineering investigation that provides continuing review of program factors. Trend analysis has two prime characteristics: investigation of actual events and comparative assessment of multiple events. Trend analysis is applied to program characteristics that vary in relation to time, sequence, or element performance. Trend analysis results are used to evaluate the operation of a program and its component systems by assessing past performance to establish baselines for current and future performance. When a valid trend exists, the accuracy of the analysis will increase as more time or event data are collected.
3. Trend analysis also is used to discover and confirm correlations between diverse factors.

201 BASIC GUIDELINES FOR TREND ANALYSIS

1. Trend analysis is a formal data analysis approach. It is not sufficient to simply plot quantitative data and superimpose a trend line. Trend analyses should measure correlation and goodness-of-fit; use normalization techniques; and qualitatively analyze results (i.e., present the management and technical reasons for the trends).
2. Significant trend analyses should include an assessment from the cognizant engineer, technician, or analyst. When appropriate, trend predictions should be included.
3. Trend analysis requirements must be included in all program planning phases to ensure the capability to provide timely analyses of testing or operational events. Planning for trend analysis must include selective data collection, development of data analysis systems, and the means for disseminating results.

202 TYPES OF TREND ANALYSIS

The NASA Trend Analysis Program comprises four interrelated elements of trend analysis: performance, problem, supportability, and programmatic. Analyses of these types can be found throughout the engineering community; however, organizing trend analysis into these specific groupings is a NASA-unique approach.

203 PERFORMANCE TREND ANALYSIS

Performance trend analyses provide a parametric assessment of hardware and software operations to forecast anomalies or potential problems. Trends are used to identify impending failure or performance degradation in hardware/software, particularly those that impact safety or mission success. Key characteristics or performance parameters (such as temperature, pressure, or erosion) are identified and evaluated to determine if they are good predictors of failure. In some cases, the characteristics are so critical to safety or mission success, that real-time performance trend analyses should be conducted.

204 PROBLEM TREND ANALYSIS

Problem trend analyses examine the frequency of problem occurrence, monitor progress in problem resolution, uncover recurring problems, and assess the effectiveness of recurrence control. A problem trend analysis frequently is an early indicator of performance or support problems, thereby generating additional analyses in those areas of trend analyses.

205 SUPPORTABILITY TREND ANALYSIS

Supportability trend analyses assess the effectiveness of logistics elements in supporting NASA programs/projects. Supportability trend analysis is concerned with the recurrence of logistics problems and the effective control of these problems.

206 PROGRAMMATIC TREND ANALYSIS

Programmatic trend analyses normally focus on institutional program-related indicators of safety or mission success. Example indicators include critical scheduling resource utilization, overtime, operational noncompliances, and time/cost.

APPENDIX A

PERFORMANCE TREND ANALYSIS

A100 INTRODUCTION

1. This appendix describes performance trend analysis and reporting. A consistent approach is established for conducting performance trend analysis and reporting the results to NASA management.
2. Performance trend analysis identifies measurable parameters that can indicate component or system degradation prior to failure. Sampling a parameter's values over time (either historical parameter values for the same hardware component or values recorded at discrete time intervals during a mission) can reveal significant trends in performance degradation prior to exceeding a redline limit or experiencing a failure.
3. Performance trend analysis can be used to detect certain types of progressive failure mechanisms prior to final failure in a system/subsystem/component. These failure mechanisms include (but are not limited to):
 - a. Wear
 - b. Erosion
 - c. Under/overtemperature
 - d. Under/overpressure
 - e. Vibration
 - f. Friction
 - g. Leakage
 - h. Material property change
 - i. Calibration drift
 - f. Contamination
 - g. Electrical resistance change.

A200 OBJECTIVE

The primary objective of performance trend analysis is to monitor hardware/software operations to forecast anomalies or potential problems of a specific system, subsystem, or component.

A201 APPLICATIONS

Applications of performance trend analysis include:

1. Perform prelaunch maintenance on systems, subsystems, and components based on early detection of degrading parameters to prevent:
 - a. Mission failure
 - b. Exceedance of Launch Commit Criteria during launch countdown, resulting in launch delay or scrub.
2. Maintain a unit in service based on trend analysis surveillance of the degradation trend line, degradation characteristics, and redundancy.

(Note that this application can be used even if a measurable unit parameter exceeds the turnaround functional test limit or normal removal time limits).

3. Provide data to support an objective mathematical risk analysis to yield a probability estimate for predicting remaining life, failure, and limit exceedance.

A300 CANDIDATES

Candidates for performance trend analysis should be based on the following primary selection criteria:

1. Criticality [based on Failure Mode Effects Analysis (FMEA) and Critical Items List (CIL) data]
2. Availability/trendability of data
3. Problem history and Engineering judgement.

A301 CRITICALITY (Based on FMEA/CIL Data)

1. Priorities for performance trend analysis should be established based on concern (risk, safety, cost, availability, or schedule) and the expected benefits.
2. Where risk is a primary concern, Criticality 1 items should be given highest priority followed by Criticality 1R and 1S items.

A302 AVAILABILITY/TRENDABILITY OF SENSOR DATA

1. A determination must be made on whether sensors are available from which to obtain performance data (i.e., instruments in place to sense measurable performance changes). When no sensors exist, the cost and benefits

of developing and installing sensors should be considered. Common performance parameters that are well suited to Performance Trend Analysis include:

- a. Pressure
 - b. Temperature
 - c. Voltage
 - d. Current
 - e. Operating elapsed time/cycle (including on/off or open/closed cycle)
 - f. Flow Rate
 - g. Torque/Motion
 - h. Given input/required output.
2. Sensor data should be analyzed to determine: a) the relationship to the condition being monitored, and b) whether these data are performance trendable. Selected parameters should be capable of showing performance degradation (with a definable upper and/or lower limit) to allow scheduled corrective action before failure. Data sampling rates, transmission rates, and system/subsystem/component degradation characteristics should be analyzed and compared to determine if the data can be trended to effectively show performance degradation.

A303 PROBLEM HISTORY

1. Selection of candidates for trend analysis includes a search of problem reporting data bases [e.g., Program Compliance, Assurance, and Status System (PCASS) and Problem Reporting and Corrective Action (PRACA) System] to identify systems, subsystems, or components with a high frequency of reported problems.
2. Problem reporting records are to be reviewed for history of maintenance problems and component problems/anomalies. This review should focus on, but not be limited to, the following areas:
 - a. In-flight/on-orbit anomalies/failures
 - b. Launch delays
 - c. Ground checkout anomalies/failures
 - d. Component removals.

A400 DATA SOURCES

The data sources for performance trend analysis include, but are not limited to the following:

1. Flight/orbital data
2. Prelaunch countdown data
3. Ground test/checkout/turnaround data
4. Teardown inspection/analysis reports
5. Acceptance Test Procedure
6. Failure analyses
7. Problem reports [including nonconformance, inflight anomaly, and unsatisfactory condition reports (UCRs)]

A500 CONSIDERATIONS

The following sections discuss factors that should be considered when conducting performance trend analyses.

A501 INDIRECT PARAMETER INDICATORS

There may be cases where a direct indicator of component performance does not exist; however, performance can be tracked through indirect indications (e.g., pressure may be an indirect indicator of temperature). In these cases, a mathematical relationship between the parameters, including advisory limits, should be developed for trend analysis.

A502 COMPLEMENTARY PERFORMANCE DATA

Many systems contain complementary or interrelated parameters. As a system (or subsystem) changes state, two or more parameters may change in a proportional or inverse proportional relationship. These complementary parameters can be used to verify the trend of a tracked parameter, thus providing redundancy and increasing confidence in the trend data.

A503 TREND LIMITS ADJUSTMENT (Based on Operating History)

Operating historical performance data gathered for performance trend analysis can be used to evaluate operating limits when it demonstrates that actual performance variability is less than was anticipated when the limits were set originally.

A504 NORMALIZING/CORRECTION FACTORS

The operating state, output, or load (about/through which a system/subsystem/component fluctuates) often cannot be controlled to achieve consistent trend data. Factors such as ambient or on-orbit conditions may affect data variability from one checkout or orbit to the next. For these cases, it may be possible to determine a normalized state, output, or load. If the relationship of the actual/normalized operating states is known, the performance trend parameter can be corrected upward or downward to reflect a normalized state. Using data from the normalized state will result in consistent trend data from checkout-to-checkout or orbit-to-orbit.

A505 PERFORMANCE MEASUREMENTS

Whenever performance data are recorded, an attempt must be made to verify the stability and slope of data approaching/departing the recorded data point. Use of a data buffer is recommended to evaluate pre-event data in verifying the slope of data approaching/departing the recorded data point. Additionally, data filtering and persistence counters should be used to verify that the data point is not a noise spike. (Whenever a performance advisory limit is exceeded, complementary data should be recorded to verify sensor condition.)

A506 DATA SAMPLING RATE

For digital samples to correctly represent an analog signal, the sampling frequency must be at twice the highest frequency component of the analog signal. This rule and its mathematical proof are the Nyquist Sampling Theorem, and the minimum sampling rate is called the Nyquist rate. If the sampling rate is too low (undersampling), the digital amplitude values would represent a low frequency alias as well as the original analog signal.

A507 DATA SAMPLING RESOLUTION

Analog signals vary infinitely amplitude and frequency. An analog-to-digital (A/D) converter cannot perfectly replicate an analog signal. At each sampling instant, there is a small but finite difference between the analog signal and the closest available digital value. This difference is referred to as quantization error, which introduces noise (known as quantization noise) to the sampled signal. The higher the resolution of the A/D converter, the lower the quantization error and noise.

A508 COMPRESSION-EFFECT ON RESOLUTION

There are numerous methods to compress data for both storage and transmission. These methods can produce either actual loss of resolution or problems in data analysis unless there is compensation for compression effects.

A509 DATA/SYSTEM STABILITY

Data/system stability must be considered in determining the amount of data required to accurately reproduce the desired trend. Reduced stability in sampled data requires increased sampling rates/resolution.

A510 CALIBRATION

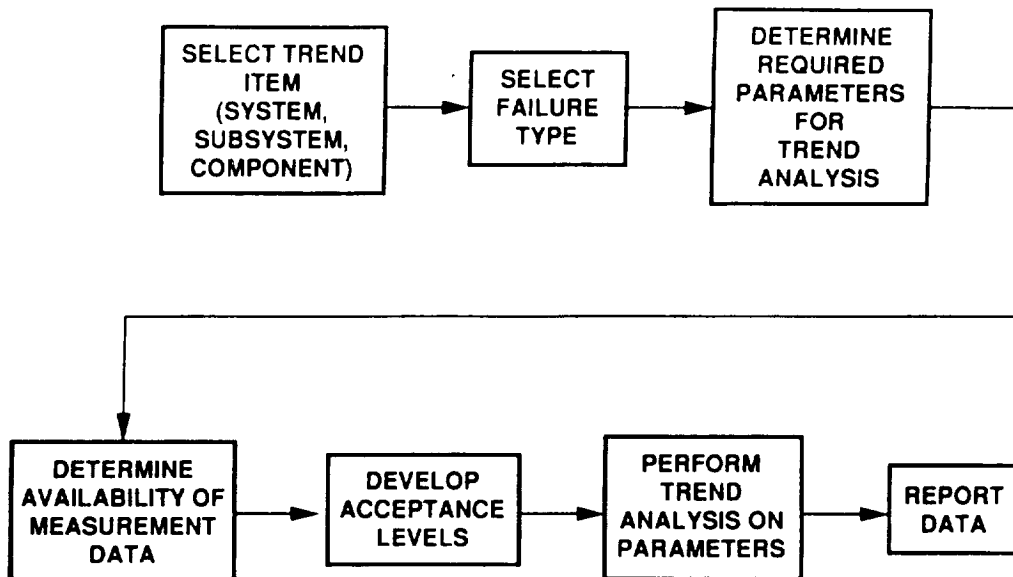
To ensure validity, calibration limits and intervals must be reviewed to determine system capabilities to produce trendable data. Resolution requirements for trendable data may exceed those required for normal system monitoring; therefore, trend analysis requirements may drive calibration limits and intervals.

A600 PROCEDURES

The basic steps (see the flow process in Figure A-1) in performance trend analysis are:

1. Analyze hardware/software systems to identify items that could lead to a critical or costly failure.
2. Prepare a list of these items as candidates for performance trend analysis. (Candidate selection criteria are addressed in Section 300 of this appendix.)
3. Select the items to be analyzed from the list of possible candidates.
4. Determine the parameters to be used in judging whether an item's performance is degrading at a rate sufficient to warrant management attention. When these parameters are critical to safety or mission success, strong consideration should be given to performance trend analysis.
5. Determine if measurement data are available for the selected performance parameters. A performance parameter may be a directly measurable factor, or a relationship between two or more parameters (i.e., pressure versus time, temperature versus pressure, etc.) based on an algorithm. If measurement data are not available, determine the feasibility of

establishing a system to measure the parameters. If feasible, then implement the measurement(s).



Performance Trend Analysis Flow Process

Figure A-1

6. Establish the performance baseline (acceptance levels or bounds).
 - a. Original equipment manufacturer's test data may be reviewed to identify failure modes that should be monitored and set performance limits for performance trend analysis.
 - b. Performance trends are identified by tracking the measurements obtained during testing and/or actual operation, and comparing these data to a defined norm or ideal performance baseline (the measurement value).
 - c. The following documents should be reviewed to determine what values represent acceptable performance for each indicator. In most cases, acceptable performance should fall within the existing operational limits, as stated in these documents:
 - (1) Operations and Maintenance Requirements and Specifications Document (OMRSD)
 - (2) Procurement Specifications

- (3) Flight Rules
 - (4) Launch Commit Criteria (LCC)
 - (5) Design Criteria
 - (6) Shop Specifications.
7. Determine the measurements necessary to evaluate the chosen parameters. The principal elements for performance trend analysis include: sensor data, time/age/cycle data collected from design and project operating elements, together with problem reports in associated data bases.
 8. Collect/measure/record the data and conduct a performance trend analysis to predict an impending failure, or ascertain the aging or degradation of an item. If the parameter being trended exceeds the historical limits or is below the performance baseline, the item could experience a failure. At this point, the decision must be made to either retain or replace the item.
 9. Report the results using charts, graphs, and recommendations.

A700 REPORTING

A701 FORMAT

1. To the extent practical, trend analysis techniques and formats should be standardized based on NASA-STD-8070.5, "Trend Analysis Techniques."
2. A trend analysis chart should display the parameters/health indicators, with appropriate analysis parameters plotted and annotated. When performance degradation of a system, subsystem, or component has been identified, the pertinent charts (or reports) should include, but not be limited to:
 - a. Item: Name of system/subsystem/component
 - b. Part No.: Manufacturing/vendor part number or end item control number
 - c. Serial Number: Identification number of the system/subsystem/part when available and applicable
 - d. Criticality: Risk category as obtained from FMEA/CIL documentation

- e. Failure Mode: Failure mode, as obtained from FMEA, that is monitored for performance degradation
- f. Failure Effect: Results of failure as obtained from FMEA/CIL
- g. Assessment and Action Required: Discussion of what corrective action, if any, is required. For example, is the system/subsystem/component approaching a catastrophic failure? Does the item need to be replaced or adjusted immediately?

A702 FREQUENCY

1. The data analyses, trend charts, and reports should be made available to program/project management via regular and special reports.
2. Routine reporting requirements should be established by program/project management. Once established, the trend reports should be updated at regular intervals. Performance trends should be reported periodically, normally by month or mission event. However, trend reports may be required more frequently, such as when trend data indicate rapid change. Trend reports also should be made available to NASA Headquarters, Code QS.
3. NASA management should be alerted in a timely manner of any performance trend analysis results that may impact safety.

This page intentionally left blank.

APPENDIX B

PROBLEM TREND ANALYSIS

B100 INTRODUCTION

1. Problem trend analysis is intended to identify recurring problems and assess progress in problem resolution or recurrence control. This type of analysis normally focuses on where the key problems are occurring and their frequency. Problem analyses (such as Pareto analysis) can be a useful starting point for focusing attention and determining where other analyses (e.g., performance trend analysis) can be of significant benefit.
2. This appendix presents a problem trend analysis approach and common techniques that serve as a baseline for NASA problem trend analysis.

B200 OBJECTIVES

The objective of the approach is to provide an historical overview of problems in an easy-to-understand graphical format. The overview should assist in decision-making relative to design effectiveness, process, or procedural changes over time (and the initiation of corrective action to improve trends).

B300 CANDIDATES

Candidate items should be comprehensive screened for selection because it is not feasible, meaningful, or cost-effective to perform problem trend analysis on all NASA items/failure modes. Basic criteria for item selection include: problem frequency, criticality, engineering judgement, and unique program/project requirements. The candidate selection process is shown in Figure B-1, "Problem Trend Analysis Selection Process Flowchart." Descriptions of the process flow elements are as follows:

1. Review documentation for trending candidates - documentation examples include:
 - (a) Indentured Parts Lists
 - (b) FMEA/CIL/CIRA
 - (c) OMRS
 - (d) LCC
 - (e) Hazard Analysis (HA)

PRECEDING PAGE BLANK NOT FILMED

- (f) NASA Center, prime contractor, or subcontractor Problem Reports
- (g) Program/project meetings.

PROBLEM TRENDING SELECTION PROCESS FLOW CHART

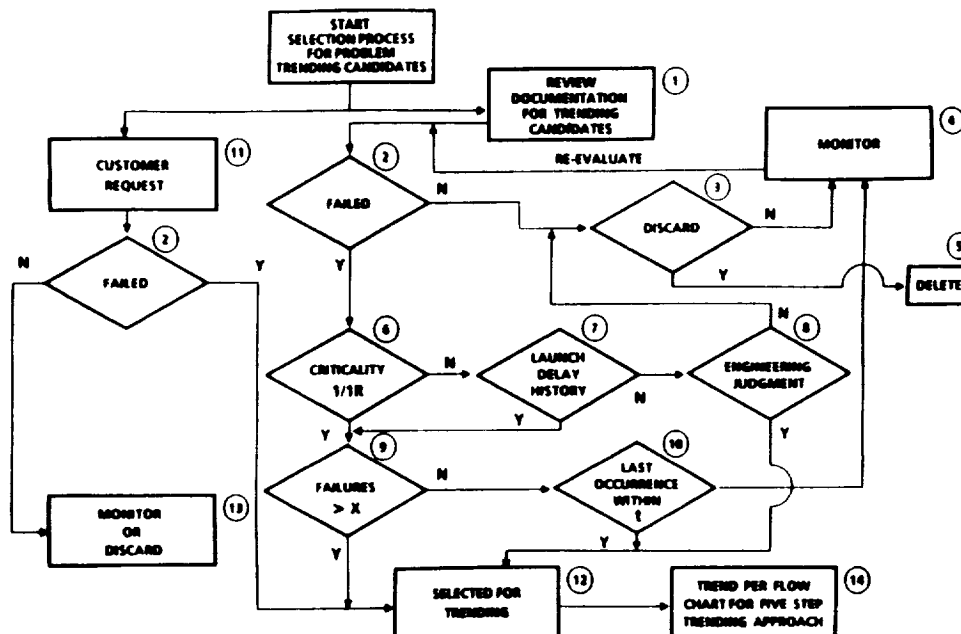


Figure B-1

- 2. Failed - Search the Center problem report data base and/or other data bases to identify failures.
- 3. Discard - Determine whether to monitor the item for possible future trend or to delete the item completely.
- 4. Monitor - Observe the item until there is justification to repeat the screening process.
- 5. Delete - Remove item from consideration for trend analysis.
- 6. Criticality 1/1R - Review failures obtained from problem report data base search.
- 7. Launch Delay History - Review failures obtained from problem report data base search to determine whether launch delays were encountered regardless of criticality.
- 8. Engineering Judgement - Assessment engineers review failures and decide whether to trend, discard, or monitor based on the technical aspects or failure history of an item.

9. Failures > X - Review failure frequency over time to determine whether trend analysis is feasible. Determine if sufficient failures are available to depict effects based on Engineering Change Proposals (ECPs).
10. Last Occurrence Within t - Consider date of last occurrence to decide whether to trend.
11. Customer Request - Process request for trend analysis without the restrictions applied to other trend analysis sources.
12. Selected for Trend Analysis - Implement actual trend analysis of selected item.
13. Monitor or Discard - Customer decides to monitor or discontinue item from further consideration for trend analysis.
14. Trend Per Flowchart for Five-Step Trend Analysis Approach - The Five-Step Trend Analysis Approach is described and illustrated in Section 600 below.

B400 DATA SOURCES

The primary sources for problem trend analysis data are the failure or problem reporting and corrective action systems, such as PRACA, supported by other data bases as required. Unless the trend analysis is uniquely directed toward the contractor's internal operation, it is preferred to use the problem reports written during and after component-level acceptance testing.

B500 CONSIDERATIONS

Fundamental areas of consideration that should be included in problem trend analyses are as follows:

1. Level of analysis (system, subsystem, or component)
2. Engineering judgement
3. Statistical analysis
4. Conflict between engineering judgement and statistical analysis
5. Data normalization
6. Adverse and favorable trends
7. Multiple failure problem reports.

B501 LEVEL OF PROBLEM TREND ANALYSIS

Trend analysis must consider specific failure modes (with knowledge of the failure mechanism/causes) to effectively evaluate a trend and make specific recommendations for corrective action. To evaluate the effectiveness of corrective actions such as design or process changes, problem trend analysis should be performed at the lowest system/subsystem/component level for which problem data are available for the failure mode involved. There are two methods for evaluating a trend: engineering judgement and statistical analysis.

B502 ENGINEERING JUDGEMENT

Engineering judgement is the basis for identifying a trend and classifying it as adverse or favorable. It applies when:

1. Sample size (quantity of problems and data points) is not sufficient for statistical trend analysis.
2. Failure mode and root cause are well understood.
3. Corrective action is well understood.
4. Statistically downward trend levels out above zero, with one or more problem reports per year in most of the recent years trended (see Figure B-2).

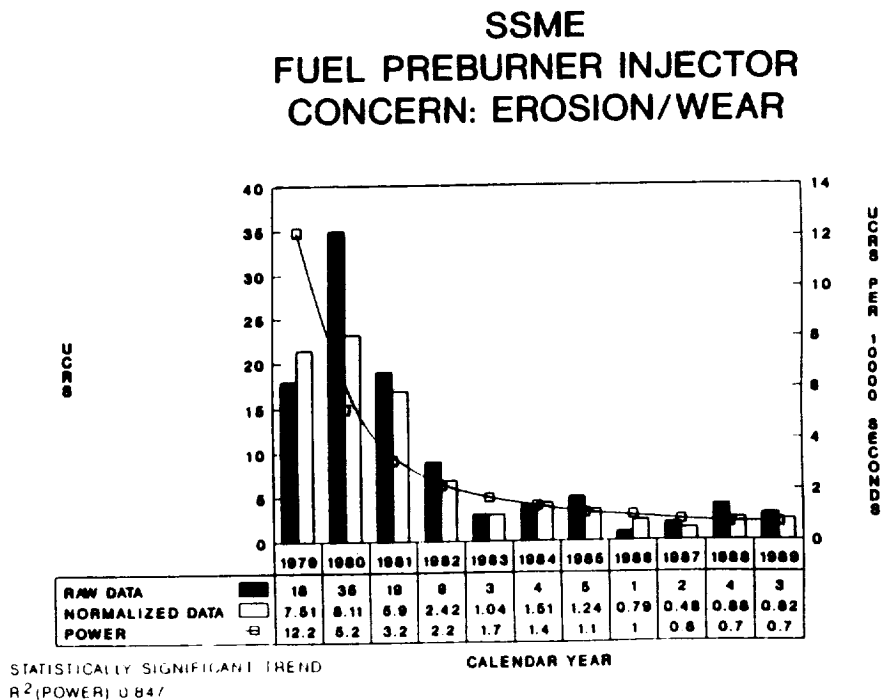


Figure B-2

5. Sufficient failure-free tests or inspections have been conducted to verify effectiveness of the corrective action.

Where practical, the results of engineering judgement should be verified by statistical analysis.

B503 STATISTICAL ANALYSIS

1. Statistical analysis of a trend should be based on a sample of at least 30 problems; however, a minimum of 5 problems (with at least 5 years of data or 5 sets of mission hardware) could suffice.
2. If corrective action is required based on a trend analysis, the failure mode(s) that constitutes the greatest area(s) of concern must be identified for trend analysis.

B504 CONFLICT BETWEEN ENGINEERING JUDGEMENT AND STATISTICAL ANALYSIS

Normally, engineering judgement and statistical analysis methods should yield the same trend conclusion (adverse or favorable). However, if there is a conflict in trend direction, engineering judgement usually is preferred for small sample sizes and statistical analysis for large sample sizes. There is no substitute for engineering judgement in assessing the importance of a trend. As an example, for extremely serious conditions, a favorable trend may only indicate that a situation is slowly improving where a more rapid trend of improvement is required.

B505 DATA NORMALIZATION

1. Prior to problem trend analysis, the quantity of problem reports per time interval (week, month, year) or per set of mission flight hardware must be normalized.¹ Examples of normalized data are:
 - a. Problems per 10,000 seconds of run time
 - b. Problems per 100 tests or inspections
 - c. Problems per mission/flow
 - d. Number of firings per year
 - e. Number of end items delivered per month.

¹ Additional information regarding normalization can be found in NASA-STD-8070.5, Section 4.4.9.

2. Data should be normalized at the lowest possible assembly level. For example, turbopumps often are shifted from engine-to-engine, and pumps are of the Phase I design. Thus, turbine blade cracking or bearing wear should not be normalized using Space Shuttle Main Engine (SSME) system-level data, but rather by the applicable Phase II turbopump design data.

B506 GOODNESS-OF-FIT

Goodness-of-fit of the trend to the data points is determined using the R-square (R^2) value. (A thorough explanation of R^2 is provided in NASA-STD-8070.5.) The highest R^2 value should be selected from one of the following trend models:

1. Linear
2. Exponential
3. Power (geometric)
4. Logarithmic (log linear)
5. Positive parabolic.

B507 TREND DIRECTION

Trend direction should be determined using the sign of the R^2 value.

1. If R^2 is less than the value in the table in NASA-STD-8070.5, pp. 4-31, the trend may be declared level. If R^2 is more than the value, it would be declared upward or downward, depending on the R^2 value sign (positive or negative, respectively).
2. Generally, a line is good for fitting upward trends; however, downward trends often are better fitted (higher R^2 value) using one of the nonlinear models. If the R^2 value is not statistically significant, it must be inferred that the trend is level or adverse. However, engineering judgement still must be applied.

B508 ADVERSE AND FAVORABLE TRENDS

The determination of the adverse or favorable nature of a trend depends upon the system that is being trended. A system that is expected to sustain a certain level of random failures would have an adverse trend if the failure rate increases or is predicted to exceed the design failure rate. A critical system that is maintained and operated to avoid

all failures would have an adverse trend if a failure mode reoccurs subsequent to the institution of failure recurrence control after the first failure. Only a result of "no problems reported in that failure mode" would be favorable; any upward or level trend would be considered adverse.

B600 PROCEDURES

B601 HIERARCHICAL APPROACH AND THE FIVE-STEP METHOD

- Figure B-3 shows typical steps used to identify a component failure mode for trend analysis. Based on the highest frequency of problem reports at each hierarchical level, one might select the element (if applicable) followed by the system, subsystem, component, and finally the failure mode.

PROBLEM TRENDING SERIES FLOW CHART

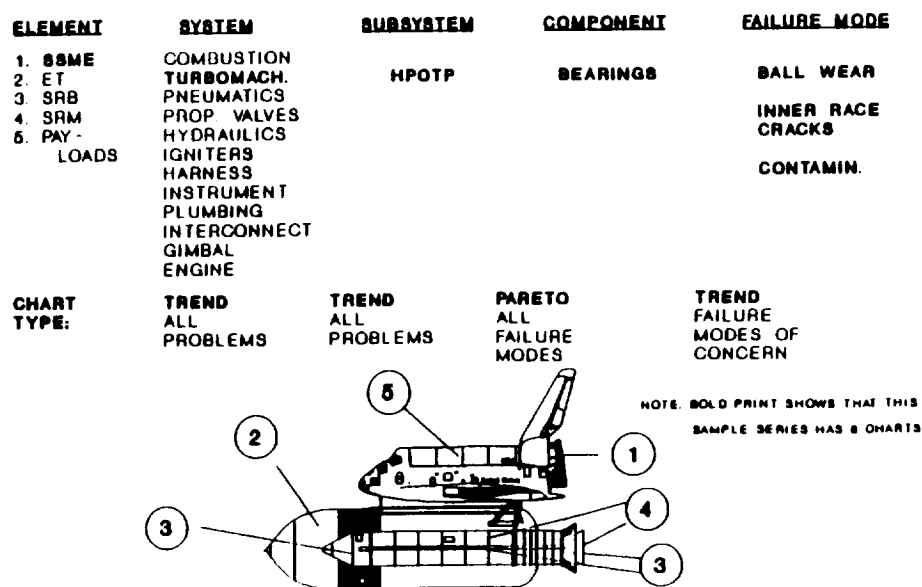


Figure B-3

- There are many valid methods of performing problem analysis; the five-step method is the recommended approach for achieving consistency throughout NASA (Figure B-4). This should not preclude the use of other methods that may be more applicable in particular circumstances.
- The five-step method of problem trend analysis comprises the following activities:
 - Research appropriate data base(s) and extract data.

- b. Construct a normalized subsystem-level or component-level trend chart.
- c. Construct a Pareto chart of failure modes/causes and identify area(s) of concern.
- d. Construct a normalized trend chart for each area of concern and failure mode.
- e. Prepare a summary assessment of the problem trend, including:
 - (1) Suspected failure mode(s)
 - (2) Root cause(s)
 - (3) Recommended or actual corrective action(s).

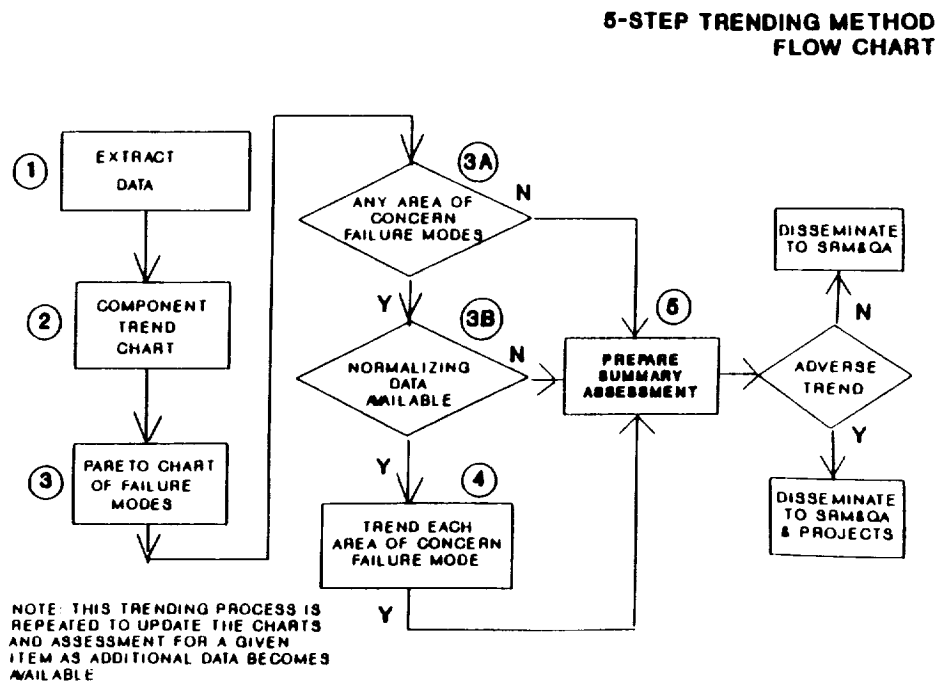


Figure B-4

B602 STEP 1: RESEARCH DATA BASE AND EXTRACT DATA

Automated data search and manual activities are necessary to obtain data for problem trend analysis. Primary considerations in Step 1 are as follows:

1. **Ground Rules for Data Inclusion/Exclusion.** In researching the data for trend analysis of a given component, the primary data source is usually the problem report data base for the cognizant design center. A second source of data may be the launch center problem report data base for flight component

problem reports. In-flight/on-orbit anomalies are available from the cognizant design, launch, and operations centers. Ground rules used in excluding data should be noted, for example:

- a. Pre-acceptance test problems
 - b. Facility/test equipment problems
 - c. Nonflight configuration problems
 - d. (Space Shuttle only) Solid Rocket Motor (SRM) and certain other hardware problems prior to post-Mission 51L redesign
 - e. (Space Shuttle only) Data from the first post-Mission 51L return-to-flight mission for each Orbiter.
2. **Data Search.** The data search should begin with the problem report data bases and include other applicable problem reports (e.g., NASA reports, contractor data). As a minimum, the data base query should include:
- a. Calendar period or mission numbers
 - b. FMEA Code
 - c. Line Replaceable Unit (LRU) Part Number
 - d. Word search for failed component/failure mode.
3. **Manual Activities.** Manual activities include, but are not limited to:
- a. Excluding nonapplicable problems
 - b. Reading problem reports to verify correct failure modes
 - c. Reviewing FMEA for assignment of new criticality categories
 - d. Obtaining time/cycle data or number of units inspected/tested for normalization.

B603 STEP 2: CONSTRUCT A SUBSYSTEM OR COMPONENT-LEVEL NORMALIZED TREND ANALYSIS CHART

The chart includes all problems (except those excluded by ground rules) on a selected subsystem or component, without identification of failure modes. Prior to trend analysis, the problem frequency is normalized by run time, cycles, sets of mission flight/orbital hardware, inspections, or other parameters. Both the raw data (quantity of problems)

and normalized data are displayed (Figure B-5). The trend direction (normalized data) may be determined by observation, or either a linear trend line or curve may be plotted. Trend direction is established by plotting all failure modes; a single corrective action is not applicable. The trend direction is observed only for information relative to overall condition of the subsystem and/or component.

SSME HPOTP SUBSYSTEM

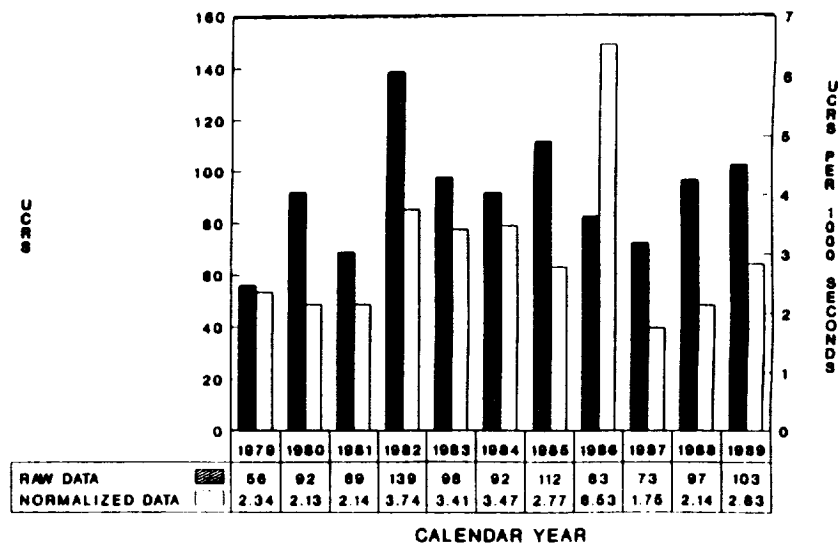


Figure B-5

B604 STEP 3: CONSTRUCT A PARETO CHART OF FAILURE MODES/CAUSES AND IDENTIFY AREA(S) OF CONCERN

1. The Pareto chart (Figure B-6) shows frequency of all observed failure modes/causes and identifies each failure mode/cause that is (from an engineering viewpoint) an area of concern. If the data base cannot sort data by failure mode/cause, it may be necessary to read each problem report on a failed component. Reviewing problem reports also may be necessary when cause codes are available because different engineers can assign different failure mode codes to identical failures.
2. As a minimum, the Pareto chart should indicate the following for each area of concern failure mode:
 - a. Quantity of Criticality 1/1R problem reports by failure mode
 - b. Percent of all problem reports by failure mode

- c. Quantity of problems reported by year (or mission)
- d. Problem report closure status (quantity open and quantity closed)
- e. Date of last failure.

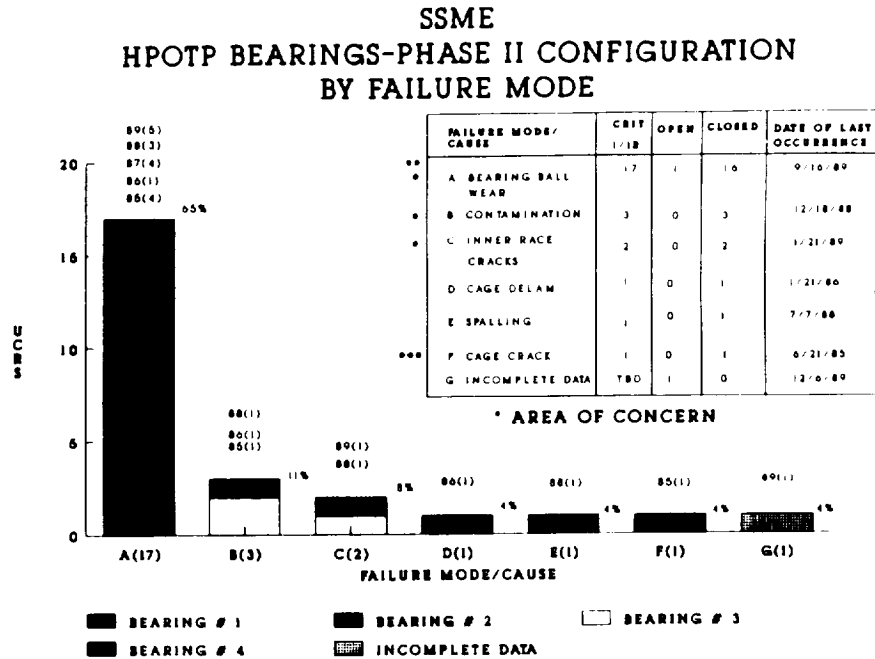


Figure B-6

B605 STEP 4: CONSTRUCT A NORMALIZED PROBLEM TREND CHART FOR AREA(S) OF CONCERN

A chart such as Figure B-7 is prepared for each failure mode or cause identified as an area of concern. Chart preparation should consider data normalization, R^2 values, design/process/procedure changes, and engineering judgement.

1. **Data Normalization.** It is important to normalize trend data whenever possible to eliminate misleading trends. Usually, low-cycle fatigue problems are normalized by exposure cycles (quantity of tests), and high-cycle

fatigue problems by operating time of exposure. In the event that problem reporting in a given area is reduced or discontinued, consideration should be given to normalizing for the reduced reporting. For example, if 20 percent of applicable problems during and after the acceptance test procedure (ATP) were due to a process that is no longer reported, the subsequent trend data should be adjusted upward (multiplied) by $1.00/0.80 = 1.25$.

SSME
HPOTP BEARINGS-PHASE II CONFIGURATION
CONCERN: BEARING BALL WEAR

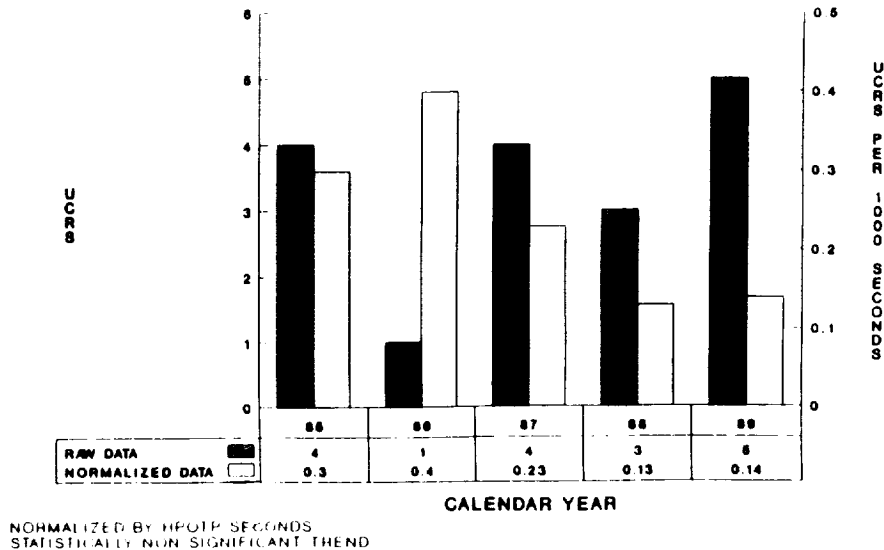


Figure B-7

2. **R² Values.** For each trend, only the models for which the fitted points have no negative values can be candidates for selection. When R² values for any of the five models (linear, exponential, power, logarithmic, or positive parabolic) are approximately the same (difference ≤ 0.020), the one that best fits the extreme right data point would be selected.
3. **Design/Process/Procedure Changes.** Design, process, or procedure changes that could eliminate the failure mode should be shown at the appropriate point on the trend chart (Figure B-8). Usually, it is desirable to show raw data and normalized data both prior to and after the design change on a failure mode trend chart. Only the normalized data are trended. It is not recommended to show a trend line or curve on the trend chart unless the trend is declared statistically increasing or decreasing. It is important to determine trend direction after the last major change point.
4. **Engineering Judgement.** If the failure mode, root cause, and corrective action are well understood and the number of subsequent tests (or seconds or inspections) without failure is considered sufficient, trends with few data points that have ended with zero failures may be declared as downward.
 - a. The example illustrated in Figure B-8 involves quantities of case-to-insulation debonds on the Redesigned Solid Rocket Motor (RSRM) based on occurrences on successive sets of mission flight

hardware. The plotted data indicate process change points on RSRM segments. Engineering knowledge of the changes plus six clevis end failure-free flights after the grit-blasting change indicates a statistically verified downward trend. Although initially considered downward, the tang end trend is not statistically significant and, therefore, is identified as an adverse trend.

REDESIGNED SOLID ROCKET MOTOR CONCERN: RSRM INSULATION TO CASE DEBONDS

REPORTED AT KSC, FINAL INSPECTION (1: 0.175" DEEP)

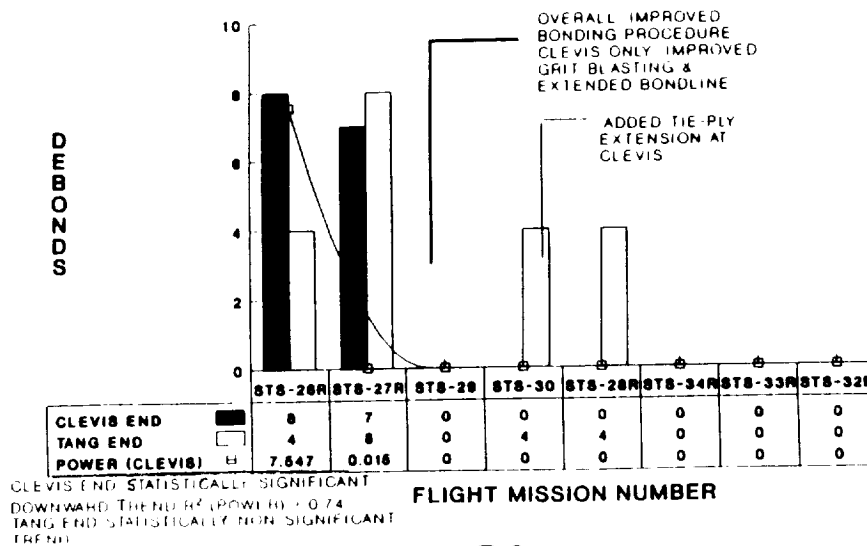


Figure B-8

- b. Figure B-9 is a backup chart useful to show location of trended problems (in this case, by flight vehicle and RSRM segment).

B606 STEP 5: PREPARE SUMMARY ASSESSMENT OF PROBLEM TREND ANALYSIS WITH RECOMMENDATIONS

A sample summary assessment is provided in Figure B-10. The following are proposed inputs for a summary assessment:

1. Data source if other than cognizant Center PRACA data base. If applicable, provide ground rules for excluded problem reports (refer to Section 602 of this appendix).
2. Component and failure mode(s) trended, including quantity of problem reports.
3. CIL Code Number.
4. Failure mode(s) criticality and date of last failure.

QUANTITY OF RSRM INSULATION-TO-CASE DEBONDS
 ≥ .175" DEPTH AT KSC PREFLIGHT, BY SEGMENT
 (BACKUP DATA)

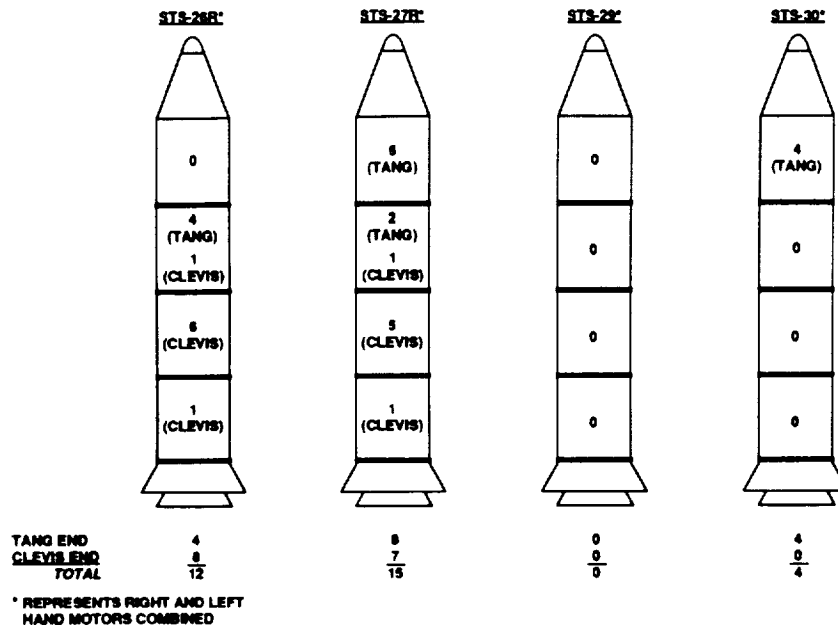


Figure B-9

5. Primary failure cause/subcause.
6. Design/process/procedure changes, with effectivity. Indicate if any data prior to such changes are excluded.
7. Trend direction (increasing, level, or decreasing).
8. Trend evaluation (adverse, acceptable, or favorable).
9. Recurrence control action.
10. If applicable, a statement regarding additional data (trend analysis update) needed to evaluate the trend direction.
11. As applicable, recommendations based on engineering analysis of the trend and a statement regarding additional resources required to correct an adverse trend. When the failure mode for the area of concern can be characterized by a variable (e.g., dimension, load, voltage), recommend performance trend analysis of the variable versus run time, cycles, or inspections. An option is to correlate the variable with influence parameters (pressure, temperature, and critical dimension).

SUMMARY ASSESSMENT (SAMPLE)
FAILURE MODE: HPOTP - LOSS OF SUPPORT OR POSITION
THIS FAILURE MODE IS FMEA CRITICALITY 1.
CIL ITEM NUMBER: B400-13
FAILURE CAUSE A: HPOTP PHASE II BEARING ANOMALIES
FAILURE SUBCAUSE #1:
BEARING BALL WEAR:
17 UCRs: MOST RECENT FAILURE OCCURRED IN SEPTEMBER 1989. EXCESSIVE WEAR CAUSED BY LOW TO NEGATIVE COOLANT VAPOR MARGIN. AT LEAST 10 OF THESE 17 UCRs WERE WRITTEN ON PUMP - END BEARING #2. THE LATEST RECURRENCE CONTROL IS TO LIMIT BEARING OPERATING LIFE TO 2500 SECONDS BY DAR. WITH REPLACEMENT OF THE 4 HPOTP BEARINGS PRIOR TO EACH FLIGHT. TREND IS ADVERSE (LEVEL).
RECOMMENDATION:
ROCKETDYNE, PRATT & WHITNEY AND MSFC DIRECT BEARING TESTING SO AS TO IDENTIFY DESIGN CHANGES THAT WOULD INCREASE BEARING LIFE BY DECREASING BALL WEAR. PERFORMANCE TRENDING OF BALL WEAR VS. RUN TIME AND CORRELATIONS OF BALL WEAR WITH INFLUENCE PARAMETERS SUCH AS INTERNAL CLEARANCE, LOX COOLANT FLOW, ETC. SHOULD BE UPDATED.
• DEVIATIONS APPROVAL REQUEST

Figure B-10

B700 REPORTING

B701 FORMAT

The format described and illustrated in Step 5 in the process (Section 607) should be used in the reporting problem trend analysis.

B702 FREQUENCY

The frequency of problem trend analysis reporting is determined by program needs; as a minimum, an overall program/project problem trend analysis should be reported monthly. Cyclic programs/projects such as Space Shuttle missions also should report problem trend analysis based on the cycles. Where programs are comprised of major elements, the elements should be reported in addition to the overall project reporting requirements.

B703 REPORTING RESULTS

Each trend analysis organization should establish a method of dissemination that meets their specific requirements. When reporting problem trend analysis results in support of management decisions, include the following activities:

1. Coordinate early trend analysis products (chart preparation) with cognizant organizations (SRM&QA, project/prime contractor, and engineering offices).
2. Establish a routine periodic hard copy distribution (e.g., quarterly, monthly) of current trend charts.
3. As applicable, maintain a display of selected current trend charts.
4. Provide trend charts for real-time support of mission reviews.
5. Provide immediate distribution of charts identifying adverse trends. If an adverse trend impacts hardware on a vehicle about to be launched, the most expeditious communication technique must be used.

B704 MAINTAINING PROBLEM TREND ANALYSIS STATUS

When selection of items for trend analysis is complete, it is essential to maintain a status or accounting system. A suggested format for this effort is provided in Table B-1, "Problem Trend Analysis Program Status." Descriptions of column headings are as follows:

1. **Element**. Selection criteria for items trended (refer to Section 300).
2. **Planned**. Number of deficient hardware items to be trended. Some planned items may not be trended because of insufficient data points, redesign, etc. The quantity in this column is equal to the sum of the next three columns.
3. **Currently Trended**. Number of items for which at least one trend chart exists.
4. **In-Process**. Number of items for which trend analysis is underway but no trend chart exists.
5. **Inactive**. Number of items planned for trend analysis, but which are neither trended nor in-process. (This category may include items that were trended, but have been temporarily discontinued.)
6. **Remarks**. Any pertinent explanatory notes.

Table B-1

PROBLEM TRENDING PROGRAM STATUS					
ELEMENT	PLANNED	CURRENTLY TRENDED	IN PROCESS	INACTIVE	REMARKS
SSME					
F - FREQUENCY	10	5	1	4	
C - CRITICALITY	2	2	0	0	
E - ENGINEERING	10	10	0	1	
M - MSFC	4	4	0	0	
ET					
F - FREQUENCY	0	0	0	3	
C - CRITICALITY	1	1	0	0	
E - ENGINEERING	1	1	0	0	
M - MSFC	0	0	0	0	
SRB					
F - FREQUENCY	13	2	0	11	INACTIVE ITEMS ARE LOW CRITICALITY AND/OR FREQUENCY
C - CRITICALITY	1	1	0	0	
E - ENGINEERING	1	0	0	1	
M - MSFC	0	0	0	0	
RSRM					
F - FREQUENCY	10	0	0	10	INACTIVE ITEMS ARE LOW CRITICALITY, LOW FREQUENCY, AND/OR WAITING RESULTS OF SUBSTANTIAL REDESIGN
C - CRITICALITY	2	2	0	0	
E - ENGINEERING	0	0	0	0	
M - MSFC	1	1	0	0	
GRAND TOTAL	79	42	1	36	
NOTE: QUANTITIES ON THIS TABLE ADDRESS THE NUMBER OF SERIES OF ITEMS. A SERIES IS IDENTIFIED ON SERIES FLOW CHART.					

This page intentionally left blank.

APPENDIX C

SUPPORTABILITY TREND ANALYSIS

C100 INTRODUCTION

1. This appendix provides a consistent approach for conducting supportability trend analysis and reporting results to NASA management.
2. Supportability trend analysis is concerned with the assessment of the effectiveness of the logistics support system. The common logistics elements include, but are not limited to:
 - a. Maintenance
 - b. Supply support
 - c. Support equipment
 - d. Facilities management and maintenance
 - e. Support personnel and training
 - f. Packaging, handling, storage, and transportation
 - g. Technical data support
 - i. Automated data processing hardware/software support
 - j. Logistics engineering support.

C200 OBJECTIVES

The primary objectives of supportability trend analysis are:

1. Monitor the current health of support systems.
2. Forecast support problems to enable resolution with minimum adverse effect.
3. Determine which support elements can be improved to optimize the system availability over its operating life.
4. Measure effects of system reliability and maintainability on supportability and identify areas for improvement.
5. Analyze current support systems to estimate future requirements.

6. Identify the relationships between support and other program/project factors.

C300 CANDIDATES

1. Because elements of supportability trend analysis are based on the common elements of logistics support and logistics engineering, the candidates for this analysis are generally well known. Candidates for trend analysis should be selected to provide an accurate measurement of the effectiveness of the support elements and the reliability/maintainability design factors.
2. Examples of common candidates for supportability trend analysis include:
 - a. Repair turnaround time (TAT)
 - b. Scheduled maintenance activity
 - c. Unscheduled maintenance activity
 - d. Modifications
 - e. Zero balance inventory items
 - f. Cannibalization
 - g. Technical documents changes
 - h. Fill rate
 - i. Impending loss of spare/repair capability
 - j. Personnel skill adequacy.
 - k. Repetitive failures.
3. Examples of supportability trend analysis candidates used to evaluate system reliability/maintainability/availability support characteristics include:
 - a. Mean-time-between-failures (MTBF)
 - b. Mean-time-to-repair (MTTR)
 - c. Mean-time-between-repairs (MTBR).
4. Priorities should be established based on the area of concern (risk, safety, cost, availability, and schedule) and the expected benefits of the trend analysis. Where risk criticality is a primary concern, Criticality 1 items should be given highest priority followed by Criticality 1R/1S items.

5. A prime concern in supportability trend analysis is the determination of the extent of analysis and identification of the appropriate parameter variation that must be measured. Selected parameters must be measurable and capable of showing sufficient variation to be useful in monitoring the factor under analysis.
6. A determination must be made if parameters are measurable, "sensors" are available to obtain supportability data, and data systems are in place to obtain/record the supportability factor. In the context of supportability, a sensor is a manual or automated method of obtaining and recording data. When no sources exist, the cost and benefits of developing and installing sensors should be considered. Consider automating data recording, storage, and retrieval when manually stored data are to be used continually or in a large number of analyses. Use of existing data systems or labor-saving methods (such as bar coding) offer the opportunity to automate data processing at minimum cost in manpower/equipment.
7. The following example illustrates the importance of selecting appropriate parameters to measure the effectiveness of a support system. A common analysis involves the time to repair/refurbish a piece of equipment from its turn-in for repair until its availability for issue in a ready-for-installation (RFI) condition. This is an appropriate way to measure the overall turnaround time (TAT) of the entire support system established for that equipment. If the goal of the analysis is to monitor the performance of a particular facilities repair process, the parameter to be measured should be the time between receipt at the maintenance facility until the item is ready for shipping back to the support site.

C400 DATA SOURCES

1. There are usually many data sources for analysis of supportability factors. Because the data sources relate to contractual and fiscal matters, the records often are recorded and stored manually. Automated data usually are confined to unique accounting systems that are not interconnected with other supportability data bases. Thus, establishing this analysis requires considerable understanding of the logistics elements and the supporting administrative systems.
2. Available data may not be in a form that is readily usable. In many cases, contractual requirements may complicate the process of obtaining necessary data. Processing certain data is so labor-intensive that the use of that data is impractical or infeasible.

Contract modifications and funds expenditures may be necessary to obtain critical data.

3. Excellent data sources for supportability trend analysis may be found in:
 - a. Equipment problem reports
 - b. Work authorization documents
 - c. Contractual acceptance records
 - d. Shipping and receiving reports
 - e. Payment records for maintenance
 - f. Transportation records
 - g. Inventory and issue/turn-in records
 - i. Training course attendance records
 - j. Technical documentation error reporting
 - k. Consumable replenishment records.
4. Each program/project should recognize the relationship between these data sources and the supportability factors. Recognizing the relationships should lead to an understanding that analysis of supportability data is often as important to a program/project as performance data.

C500 CONSIDERATIONS

There are many factors to be considered for a supportability trend analysis, including:

1. Maintenance operations
2. Selection criteria
3. Line items/spare parts
4. Indirect indicators
5. Complementary data
6. Trend limits
7. Normalization factors
8. Causes of delayed data
9. Data accuracy.

C501 MAINTENANCE CONCEPT

Maintenance operations are performed within a three-level structure: Organizational, Intermediate, and Depot. Each action is assigned to the level at which it can be accomplished most effectively. Organizational level maintenance may be considered on-line operations, while Intermediate and Depot level maintenance may be considered off-line maintenance. A system maintenance concept may involve any combination and degree of maintenance levels. In many cases, only one or two of the levels are used.

C502 SYSTEM/SUBSYSTEM/UNIT SELECTION CRITERIA

The program/project should prioritize systems, subsystems, and LRU/Orbital Replaceable Units (ORU) prior to selecting areas for trend analysis reporting. Prioritization should consider areas such as functional criticality, cost, failure rates, MTTR, maintenance demand rates, and repair TAT. The list of selected items should be reviewed and updated as required.

C503 LINE ITEMS/SPARE PARTS

Supportability trend analysis commonly analyzes line items, which are inventory items that have unique part numbers. Some analyses of line items do not consider the quantities of the line items; users must consider whether the reference to the number of line items includes the quantities of each line item involved. Analyses, such as line-items-below-minimum-balance are concerned with the status of the line items rather than their quantities.

C504 INDIRECT PARAMETER INDICATORS

Where a direct indicator of component supportability does not exist, supportability may be tracked through an indirect indicator. A mathematical relationship between parameters, including advisory limits, is developed to translate the measured parameter to the analyzed parameter.

C505 COMPLEMENTARY DATA

In systems where more than one parameter may be used as a direct indicator of supportability, one parameter is selected for use. When practical, complementary trend analysis of a second parameter may be used to verify a trend (redundancy) and increase confidence in the primary analysis.

C506 TREND LIMITS ADJUSTMENT BASED ON OPERATING HISTORY

As operating history is compiled for each supportability indicator, the supportability limits should be evaluated for revision if the historical baseline (norm) consistently differs from the original. Reestablished limits must be consistent with program/project goals.

C507 NORMALIZING/CORRECTION FACTORS

Support operations are subject to variables such as schedule delays or funding availability. While it may not be possible to control these factors, it is possible to analyze the operation by adjusting the measurement of the support element to compensate for the variable. If the relationship of the actual and normalized operating states is known, the supportability trend parameter can be corrected upward or downward to reflect a normalized state. Using data from a normalized operating state should produce consistent trend data from one mission or period to the next.

C508 DATA DELAY

Because a large amount of the data used for supportability trend analysis is captured in writing or unique data bases, the time to review and process the data often precludes determination of current program/project status. Trend reports should annotate the time factor and provide a clear method of estimating current status using the data available at the time the report was prepared.

C509 DATA ACCURACY

Experience shows that minor inaccuracies can develop in any data recording system. The program/project periodically should examine the data for accuracy. If errors are found, the data still may be useful for trend analysis. Even if the absolute values of the data are erroneous, the supportability trend analysis of the data may yield useful comparative trend information if the errors are caused by consistent miscalculations.

C510 CORRECTIVE ACTION

The following examples illustrate actions that may be taken to correct adverse supportability trends:

1. Given an unusual demand on spares or maintenance capabilities, increase resources to meet increased usage. Investigate the cause of the upsurge in demands to correct the situation.

2. Measure the effects of system reliability and maintainability characteristics on support factors. For systems that do not meet design supportability, increase the level of maintenance/provisioning and recommend design modifications to improve life-cycle support.

C600 PROCEDURES

The basic steps in supportability trend analysis are:

1. Analyze the operations and support systems to identify items that could lead to a system failure, schedule delay, or cost increase if support degrades.
2. List these items as candidates for supportability trend analysis.
3. Select items from the list of possible candidates. Provide the list of items to the Program/Project Office.
4. Determine the parameters to be used in judging whether the item's supportability is fluctuating at a rate sufficient to warrant management attention. When these parameters are critical to safety or mission success, strong consideration should be given to the feasibility of performing trend analysis.
5. Determine if measurement data are available for the selected supportability parameters. Supportability parameters may be directly measurable factors or the relationships between two or more parameters based on an algorithm. If measurement data are not available, determine the feasibility of establishing a system to measure the parameters.
6. Establish the supportability baselines and limits. Original baselines and limits should be taken directly from program/project support requirements. The following documents are examples of the type of sources that should be reviewed to determine what values represent acceptable supportability for each indicator:
 - a. OMRSD
 - b. Logistics Support Plans
 - c. Design Criteria
 - d. Program Requirements Documents
 - e. Specifications

- f. Intermediate and Depot Maintenance Requirements Documents (IDMRDs).
7. Determine the measurements necessary to evaluate the chosen parameters.
8. Collect/measure/record the data and perform a supportability trend analysis to determine if the parameter being trended exceeds the historical limits or falls below the supportability baseline. If so, immediate management attention may be needed to correct the situation. If the values are within limits but the trend indicates that they may exceed the limits in the future, this early warning allows management to implement preventive measures before the situation deteriorates.
9. Report the results using charts, graphs, and recommendations.

C700 REPORTING

C701 FORMAT

1. To the extent practical, trend analysis techniques and formats should be standardized based on NASA-STD-8070.5, "Trend Analysis Techniques."
2. The supportability element chart should depict an historical trend of substantiated data on the characteristic being measured with realistic program/project control limits for that subsystem or repair location. When an adverse trend has been identified or a control limit has been (or is expected to be) exceeded, a detailed analysis should be provided, including a discussion of what corrective action, if any, is required.

C702 BASIC SUPPORTABILITY ANALYSES

The following paragraphs provide examples of common supportability trend analysis reports that are used. These examples are not the only forms of supportability trend analysis that can be performed and reported. For simplicity, months are used to exemplify time periods and missions to exemplify events. Where reusable vehicles are involved (the Space Shuttle Orbiter, for example), vehicle differences may require analyses by vehicle as well overall analyses by vehicle type.

1. LRU/Spares/Line Item Demands Filled Per Month/Mission/Vehicle. This report analyzes the number of demands that were filled for LRUs/spares or line items,

generated by planned and unplanned work requirements. Analyses of line items must clarify whether or not the numbers reflect the quantities of each line item. The subject is discussed in Section 503 (refer to Figure C-1).

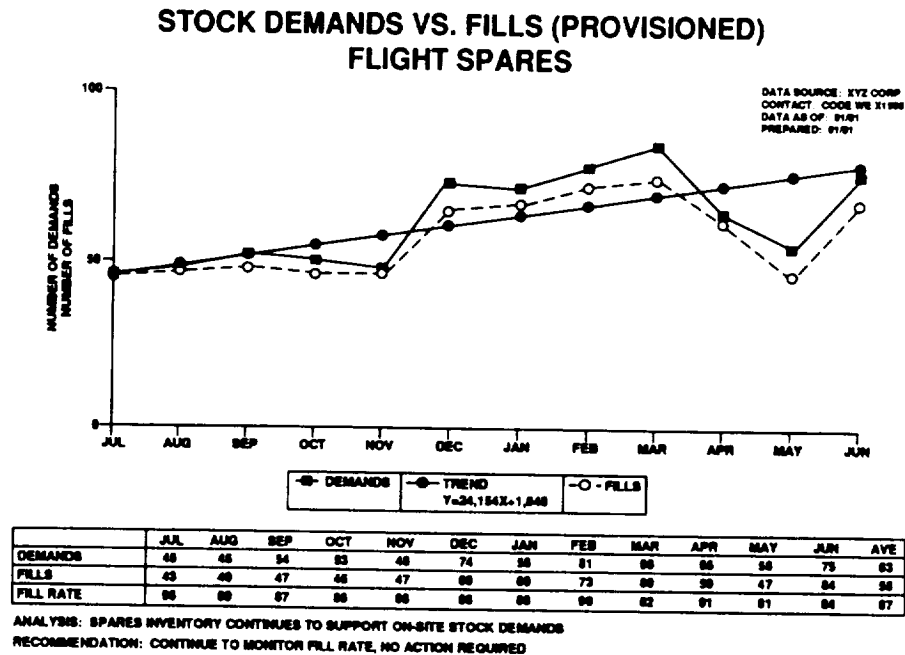
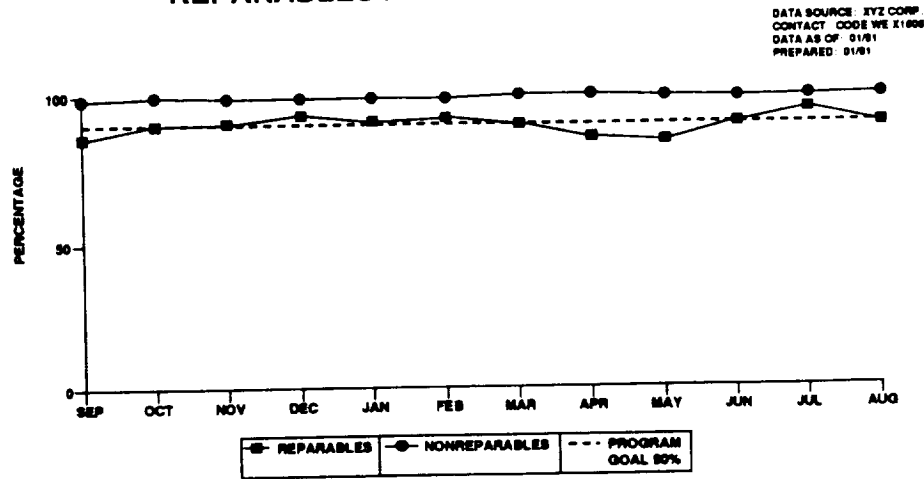


Figure C-1

2. **LRU/Spares/Line Item Demand Fill Rate Per Month/Mission.** The previous report is useful for inventory management; this report is most useful as a measure of effectiveness for the supply support system. This report displays the data from the previous report on a percentage scale on the ordinate (y axis) and time or event/mission sequence on the abscissa (x axis). By measuring the percentage of the demands actually filled, this report shows the ability of the support system to meet the demand for replacement items. Normally, a supply support system cannot meet all demands; therefore, a program/project goal or limit is set, based on a trade-off of cost and availability. This analysis shows supportability of the supply system relative to the program/project goal. As a form of supportability trend analysis, this report can be used to anticipate when a supply support system should degrade below the acceptable Probability of Sufficiency (POS) factors specified in program/project documents (refer to Figure C-2).

FLIGHT SPARES FILL RATE (PROVISIONED) REPARABLES AND NONREPARABLES



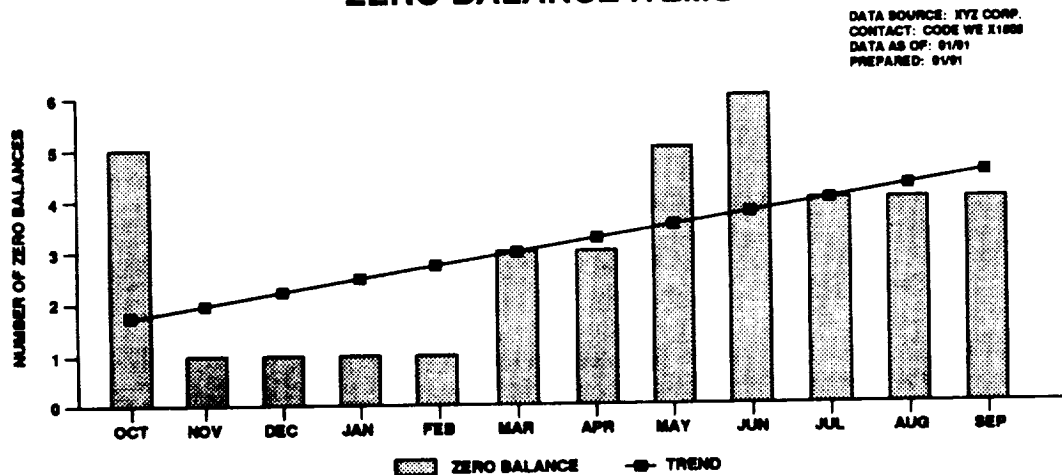
	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	AVE
REPARABLES	94.6	95.8	96.3	95.1	91.9	91.9	90.8	87.5	84.9	90.4	94.9	90.1	90.6
NONREPARABLES	98.9	99.5	99.2	99.2	99.2	99.0	99.4	99.8	99.5	99.2	99.7	99.8	99.4

RECOMMENDATION: CONTINUE TO MONITOR FILL RATE AND REPAIR TURNAROUND TIME (RTAT)

Figure C-2

3. **Zero Balance.** This report provides the trend of out-of-stock line items (zero balance) in the spares/supply inventory of provisioned items (refer to Figure C-3). Historical and projected trends are included.

ET SUPPORTABILITY TRENDS ZERO BALANCE ITEMS



DEFINITION: ZERO BALANCE INDICATES NO SPARES IN STOCK: ALL SPARES HAVE BEEN CONSUMED

ANALYSIS: TREND IS POSITIVE INDICATING A POSSIBLE IMPACT TO SUPPORTABILITY

RECOMMENDATION: CONTINUE TO MONITOR

Figure C-3

The total number and individual part numbers may be detailed by Criticality codes such as 1/1R/1S.

4. **Expedite Actions Per Month.** An expedite request must be filled within 24 hours. This report shows the expedite supply actions by month for the past year, and highlights the top 10 expedite requests (whether filled or not), including those replaced by cannibalization action or withdrawn when they were not filled. Specific items that required two or more expedite actions during the past year often are reported (refer to Figure C-4.)

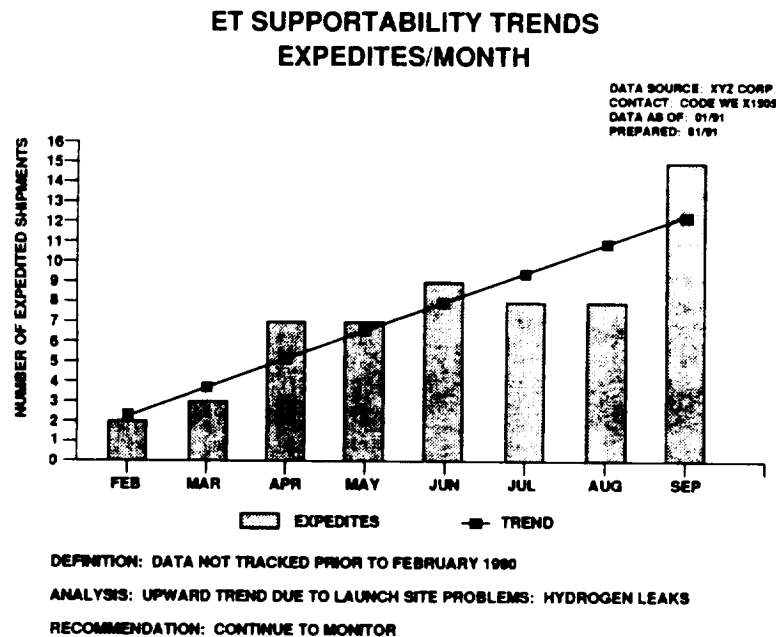
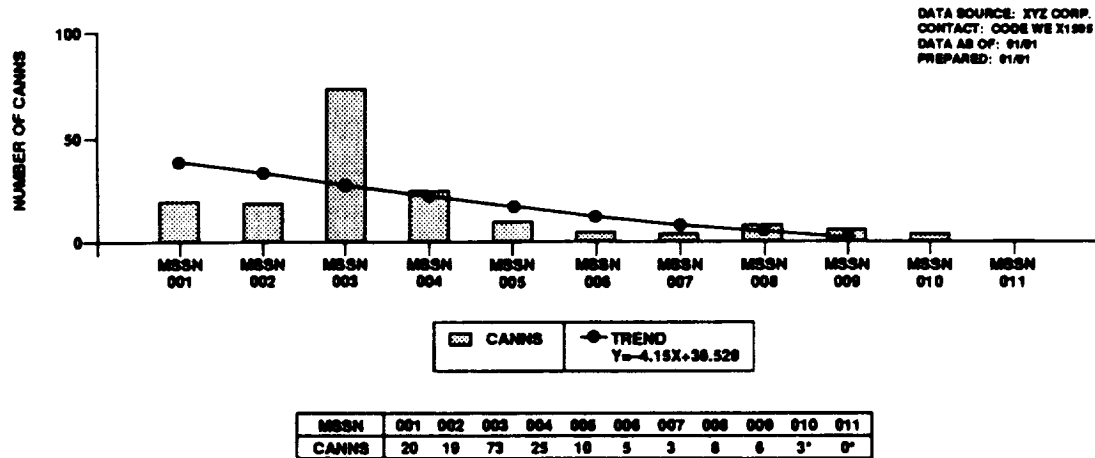


Figure C-4

5. **Number of Items Cannibalized Per Month/Mission.** This report provides a history of the number of cannibalized items by month and mission/event with projected trends. This information is presented in a line graph report with detailed part number listings as background data (refer to Figure C-5).
6. **Maintenance Tasks Per Month/Mission.** This report details the total number of scheduled/unscheduled maintenance tasks and modification tasks completed per month/mission (refer to Figure C-6).
7. **Maintenance Tasks Completed/Deferred/Waived.** This report supplements the previous one by comparing completed tasks with the deferred and waived tasks. The breakout of tasks shows capability of the support program to maintain a repetitive operation. As an

TREND OF LRU CANNIBALIZATIONS BY MISSION



ANALYSIS: DECREASE IN CANNIBALIZATIONS DUE TO JANUARY 1987 PROVISIONING POLICY CHANGE

RECOMMENDATION: MONITOR THE SPARES SYSTEM TO ENSURE PROPER CORRECTIVE ACTION

* = INTERIM COUNT

Figure C-5

TOTAL MAINTENANCE By Missions

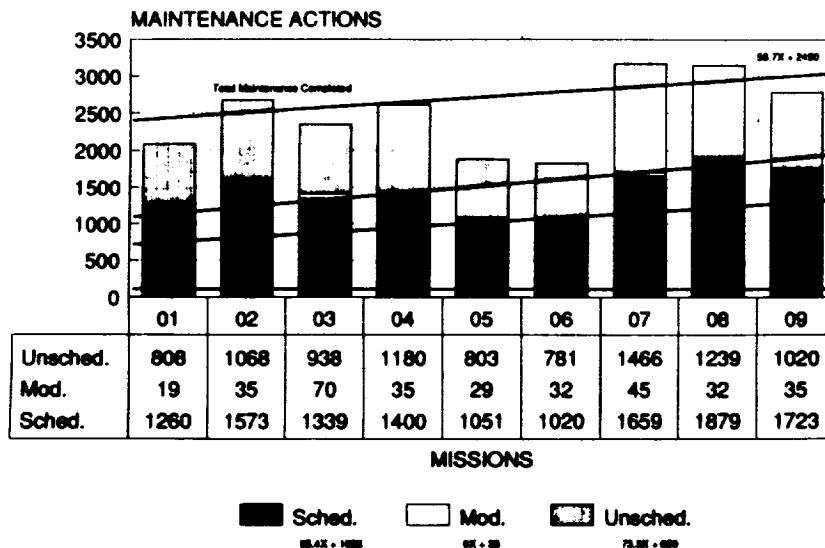


Figure C-6

example, if the overall number of completed tasks tend to remain level while the number of deferred tasks increases, program management has an indication that the support system does not have the required capacity.

The shortfall is being accommodated by the increasing number of deferrals (refer to Figure C-7).

MAINTENANCE STATUS COMPLETED/WAIVERED/DEFERRED

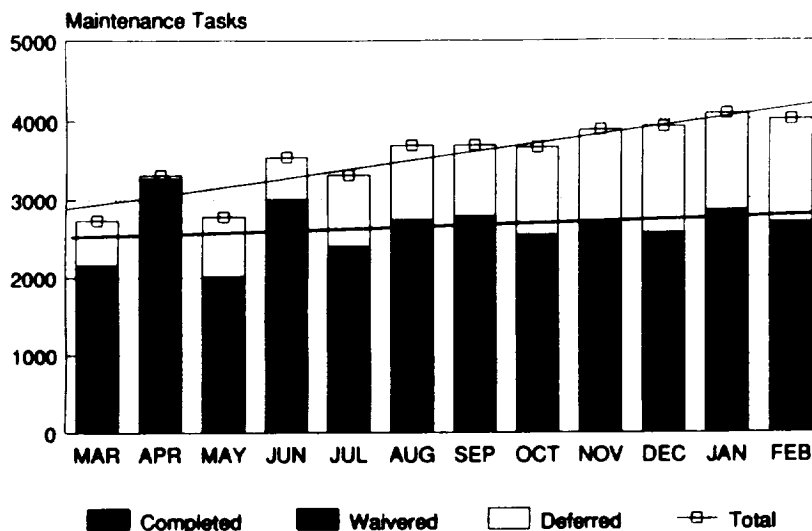


Figure C-7

7. **OMRSD Requirement Changes Per Month/Mission.** This report shows the number of OMRSD changes per month/mission. It delineates the number of changes submitted versus approved for each major element (such as Work Package, major system, power system, Orbiter, ET, SSME, etc.). This report also can show the number of waivers and exceptions by month/mission, and the number of new requests (refer to Figure C-8).

8. **Crew Maintenance Time Per Month/Mission.** This report shows the total number of man-hours expended per month for on-orbit maintenance by the crew and the average number of hours per individual actually performing maintenance tasks. Control limits on crew time for space flight system maintenance are specified in the program/project function and resource allocation requirements. For launch-and-return missions, the maintenance should be normalized as maintenance time per flight hour (refer to Figure C-9).

OMRSD RQMNTS CHANGES BY LAUNCH EFFECTIVITY

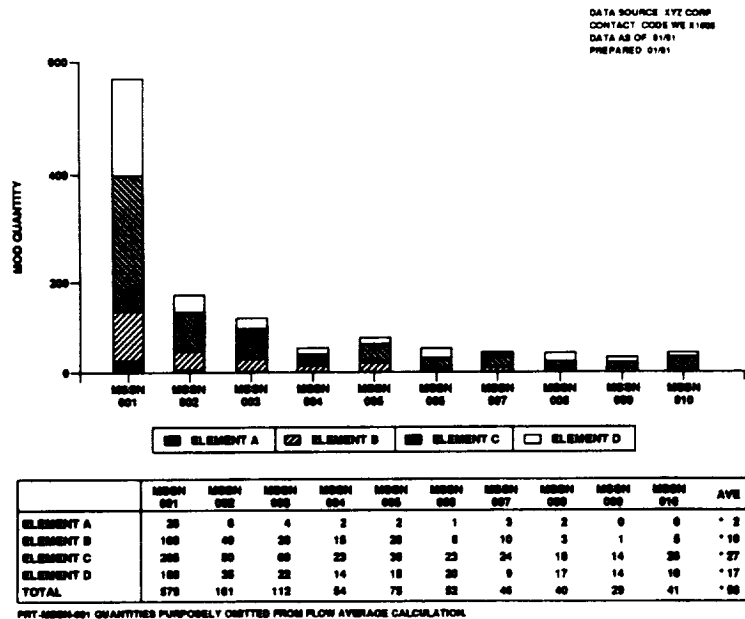


Figure C-8

CREW MAINTENANCE MAINTENANCE HOURS PER FLIGHT/ORBIT HOUR

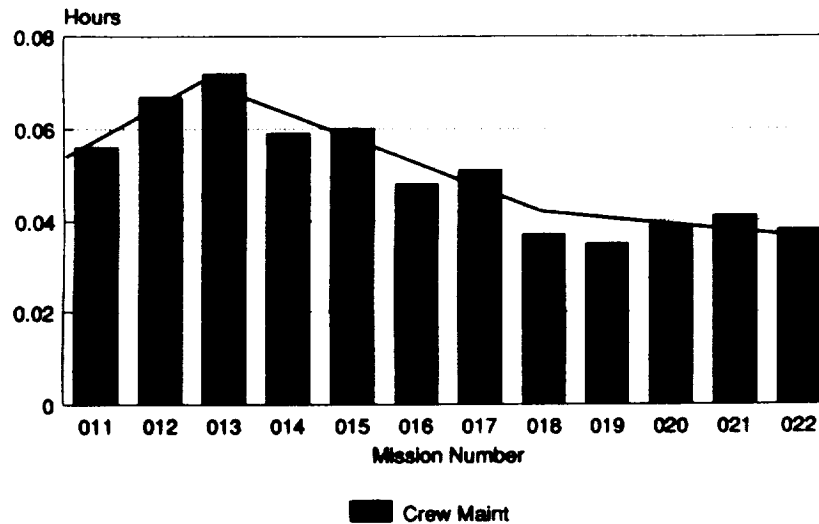


Figure C-9

9. **TAT Per Repair Agency Per Month.** This report shows the status and trends of the repair TAT by agency per month (refer to Figure C-10).

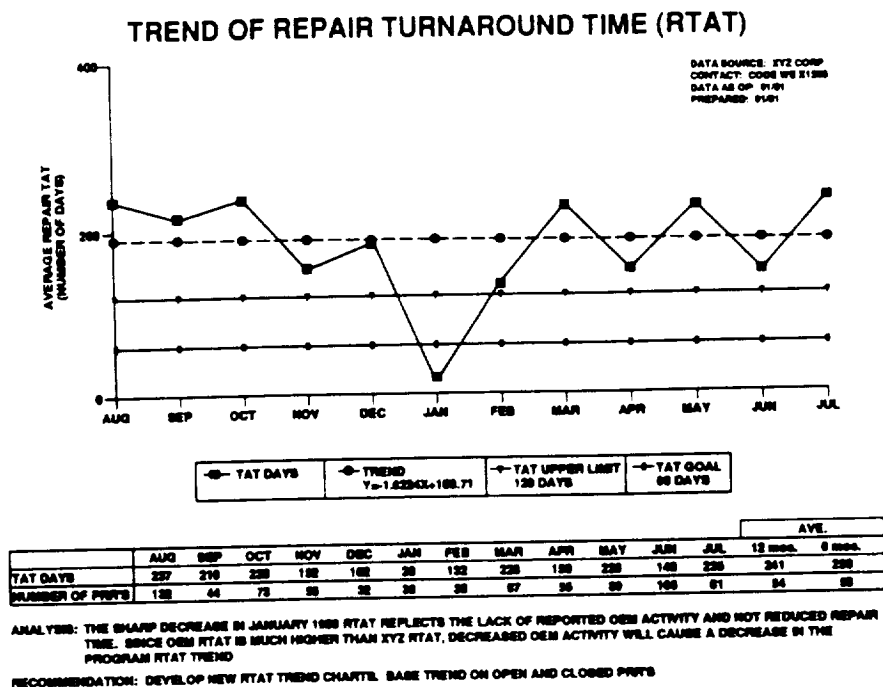
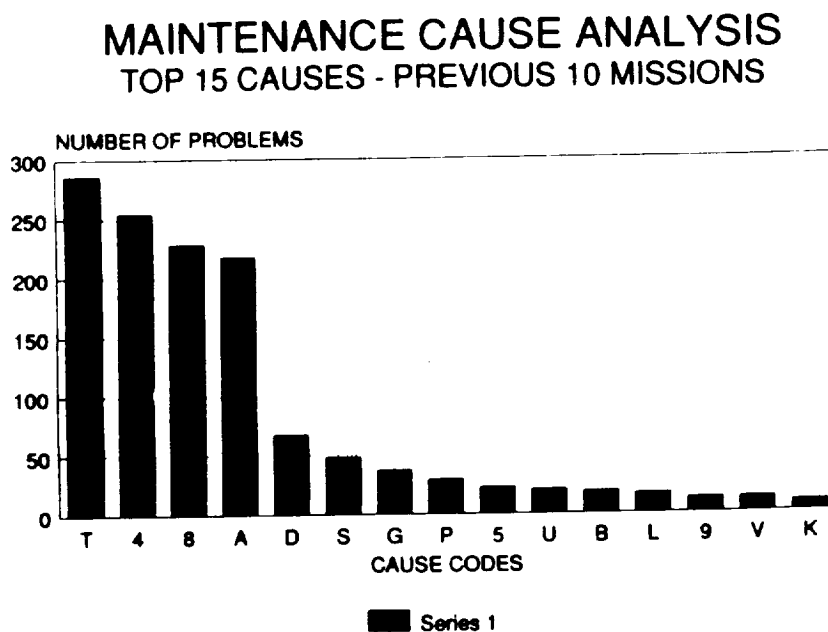


Figure C-10

10. **Maintenance Action By Causes Per Month/Mission.** This report illustrates the breakout of support problem causes. It shows if any cause has an unfavorable trend in comparison to other causes (refer to Figure C-11).



CODES LISTED IN NASA 1234.56A

Figure C-11

C703 FREQUENCY

1. The data analyses, trend charts, and the above reports should be made available to the program/project via regular and special reports.
2. Routine reporting requirements should be established by the program/project managers. Once established, the trend reports should be updated at regular intervals, usually monthly and/or by mission/event. When trend data indicate rapid change or that timely availability of trend analysis is required, the trend reports may be prepared on a more frequent basis. Copies of the trend reports should be made available to NASA Headquarters, Safety and Risk Management Division (Code QS), and the cognizant Associate Administrator for the program/project.
3. NASA management must be alerted in a timely manner of any supportability trend analysis results that may impact safety.

APPENDIX D

PROGRAMMATIC TREND ANALYSIS

D100 INTRODUCTION

Programmatic trend analysis is a tool to assess program information such as schedule elements, employee utilization and attrition rates, overtime, noncompliance with operating procedures, equipment damage, mishaps/injuries, past program performance, and any similar data to identify problems in applying resources to comply with procedural requirements and manage program schedules.

D200 OBJECTIVES

The principal objective of this analysis is to provide a medium that accurately and quantitatively monitors the programmatic posture and provides management visibility to determine the current/projected health of the human support element. Other important objectives include:

1. Increase management awareness of inappropriate demands on human resources (workload or schedules) required to support the program/project and associated hardware/software.
2. Prevent possible compromises or delays in mission schedules caused by dysfunctional responses by the human element to stress.
3. Support management in identifying schedule, human resource allocation, experience or qualification mismatches that could have potential adverse effect on the program schedule or performance. This may require procedural, assignment, or schedule modifications to maintain or enhance performance.
4. Support management in identifying areas requiring attention (such as damage, mishaps, or injuries rates). Determine the correlation with overtime or other potential program-related indicators.
5. Support proposed program/project improvement changes.
6. Support management in identifying and monitoring program/project Management Performance Indicators (MPIs) over time to assure process controls. These indicators directly affect the ability of an end-product to perform safely and reliably.

D300 CANDIDATES

Programmatic data should be used to monitor and report on, but is not limited to, the following areas:

1. Manpower strength by specialty, experience, qualification, certification, and grade.
2. Personnel attrition/turnover rates by discipline.
3. Schedule changes/slippage/or overages.
4. Overtime usage versus approved policy.
5. Incidents such as damage/fire, mishap, or injury.
6. Requirement changes, including waivers and deviations.
7. System nonconformances and problems caused by human error.
8. Rework expenditures.

D400 DATA SOURCES

1. The data sources for programmatic trend analyses are more varied than for any other type of trend analysis. In most cases, program/project offices maintain data bases that provide appropriate data or have the potential to yield MPIs with minimal modification. On newer programs/projects, integrated data systems such as the Space Station Freedom Program Technical and Management Information System (TMIS) have been created to increase access to, and speed analysis of, program data.
2. Excellent data sources for programmatic trend analysis may be found in:
 - a. Budget planning and expenditure reports
 - b. Program/project schedules
 - c. Quality assurance records
 - d. Test and development status reports
 - e. Inventory records
 - f. Equipment problem reports
 - g. Contractual acceptance records
 - h. Shipping and receiving reports

- i. Work authorization documents
- j. Manpower status reports
- k. Resource utilization records
- l. Safety reports
- m. Management Information Centers (MICs).

D500 PROCEDURES

D501 STANDARD DATA

1. Each program/project should compile data as described in Section 700 of this appendix and the referenced figures.
2. Programs/projects should maintain the list of elements for which they will supply programmatic data; ensure the validity of the data provided for programmatic trend analyses; develop required analytical techniques and controls; and determine the structure for project data collection, maintenance, and reporting.
3. Data should be made available to program management, either displayed on a separate chart for each programmatic indicator selected for trend analysis or in aggregate data reports. If work unit codes are defined for the program, they may be used to identify or reference subsystems in an element.
4. Each chart should display an historical trend of substantiated data on the programmatic indicator(s) being measured along with the realistic control limits established for that indicator by the responsible program/project. When an adverse trend has been identified (whether apparent or not from the summary trend information) or a control limit has been exceeded as a result of a trend, an analysis of that trend should be conducted.
5. Each program/project should accumulate data on programmatic indicators through completion and closeout.

D502 PARAMETERS

Suggested programmatic trend analysis indicators are contained in Section 701 of this appendix; however, programs may use other indicators. The appropriate program/project should define the indicator(s) to be used. Parametric limits may be set by policy, work standards, or directives.

D600 REPORTING

D601 FORMAT

1. Programmatic trend analysis should be prepared with sufficient detail to assist management in identifying problems and taking appropriate action. The minimum content and format for the reports are defined in this section. Reporting should highlight high risk and problem areas to aid in identifying needed improvements and program progress/health.
2. To the extent practical, techniques and formats for programmatic trend analysis should be standardized based on NASA-STD-8070.5, "Trend Analysis Techniques."
3. The following list of suggested programmatic trend analysis indicators may be expanded/modified as the program/project and programmatic trend analysis matures. Other indicators may be tracked and maintained by the programs/projects at their discretion.
 - a. **Manpower Strength.** The number of personnel assigned to the program/project should be reported each month (Figure D-1) through the program management information system (MIS). A history of the number of personnel assigned to each program should be included in a graphical report of overall personnel totals by month. Additional charts (Figure D-2) should show personnel totals by discipline and by percent change of individuals. Trends of changes in personnel assigned by total and by disciplines should be compared with an overall average change rate to determine if unusual turnover is reflected. At least 12 months should be reflected in each monthly report.

PROGRAM MANPOWER

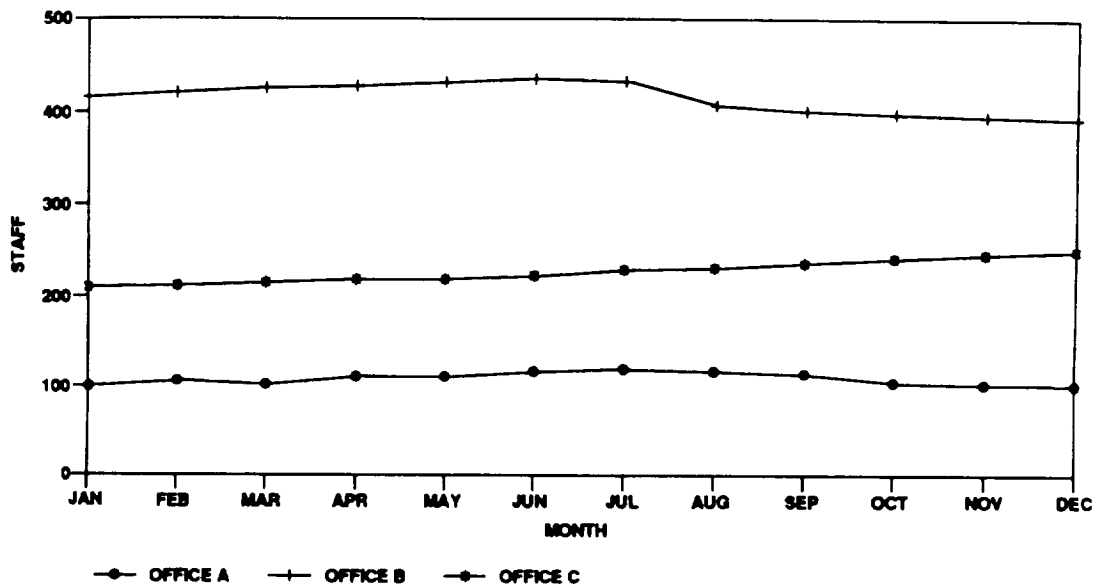


Figure D-1

PROGRAM MANPOWER BY DISCIPLINES

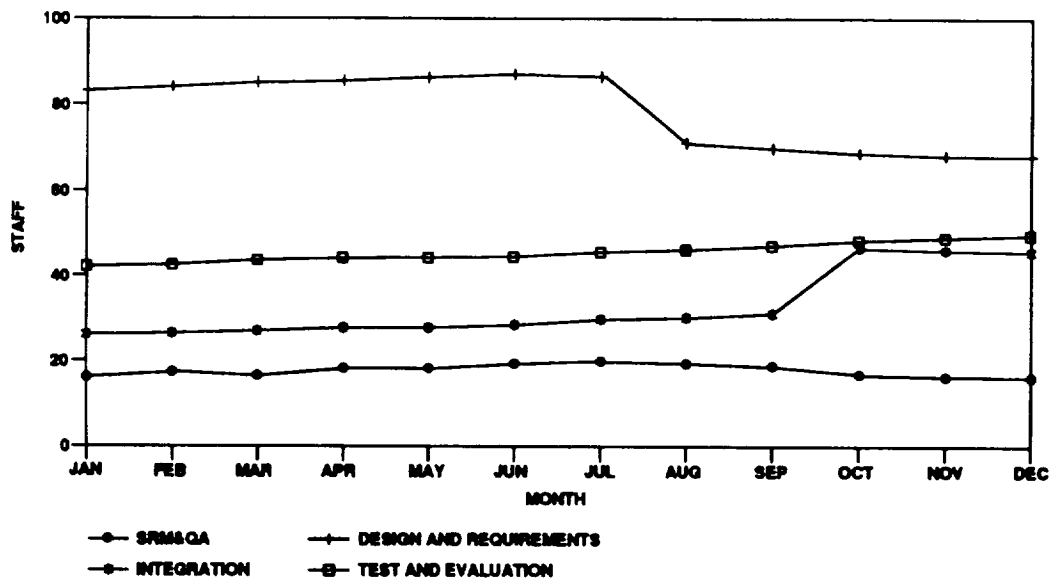


Figure D-2

- b. Schedule Changes Per Month. This report (Figure D-3) should detail the schedule deviations per month for the past 12 months, including total number of schedule deviations and the average amount of monthly deviation. When a schedule for a particular activity or milestone is changed two or

more times, the affected activity should be highlighted and explained in the monthly report.

MONTHLY SCHEDULE CHANGES TEST AND EVALUATION

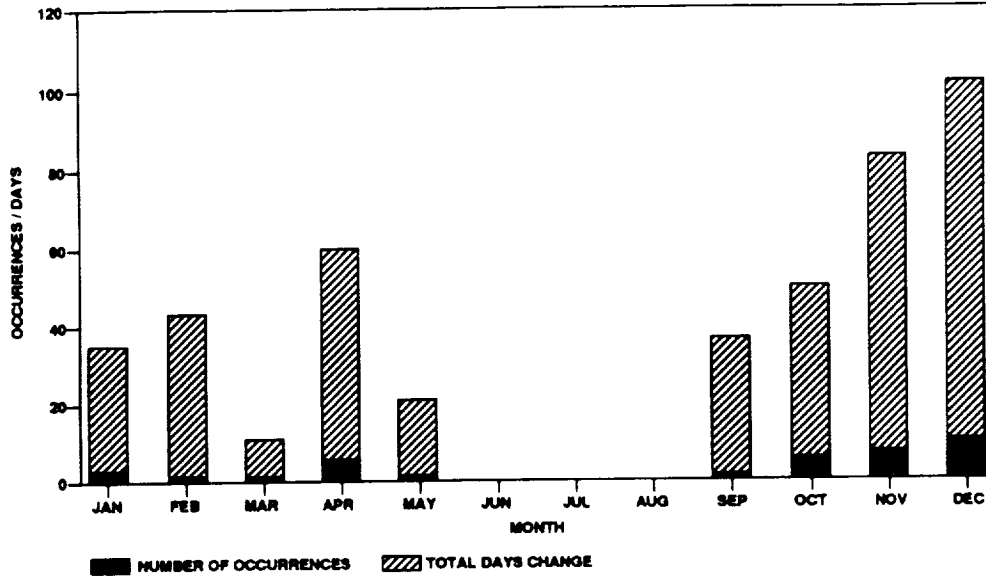


Figure D-3

- c. Overtime Usage Per Month. This report (Figure D-4) should track the total amount of overtime beyond a 40-hour work week.

MONTHLY OVERTIME PERCENTAGE OF TOTAL WORK TIME

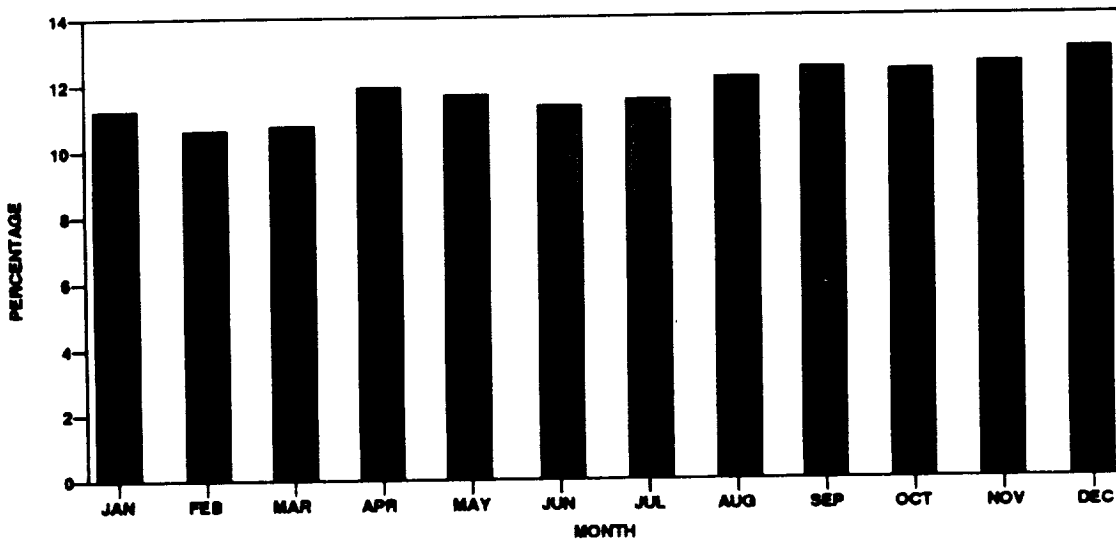


Figure D-4

- d. Incidents Per Month. This report (Figure D-5) should include the incidents per month for the preceding 12 months. The major elements of this report should be: damage, injuries, and major mishaps per A/B/C category. Graphs should be presented to display the number of incidents and cost of each category, where applicable.

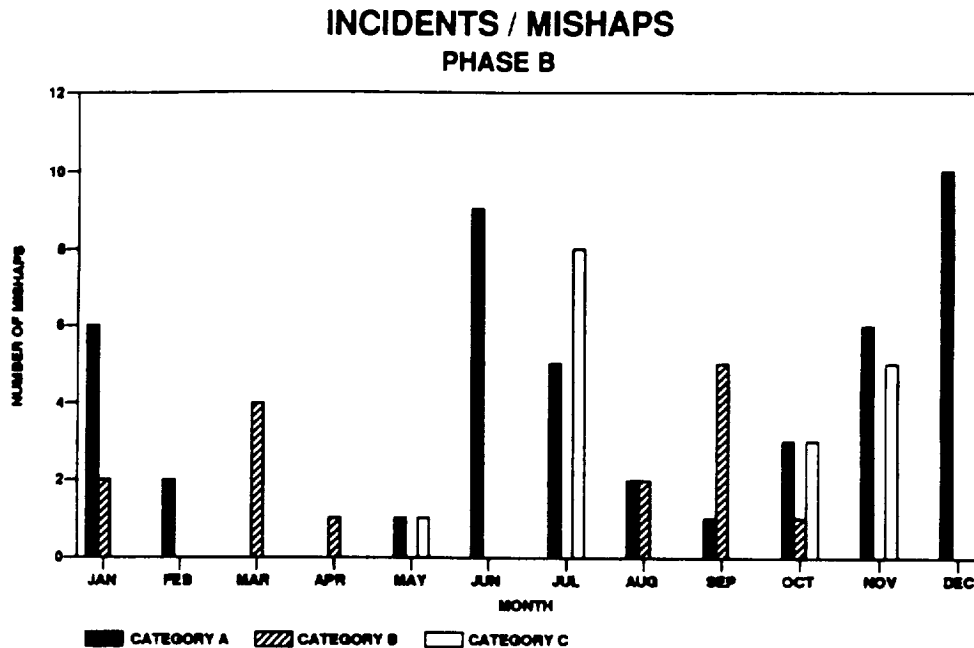


Figure D-5

- e. Requirement Changes Per Month. This report should show the number of changes to the top-level operational and maintenance requirements document per month for the last 12 months (Figure D-6). It should delineate the number submitted versus the number approved, by major element. Waivers and exceptions, and the number of new requests, should be shown by month (Figure D-7).

D602 FREQUENCY

Frequency of programmatic trend analysis should be specified by the cognizant program/project office.

OMRSD CHANGES PROGRAM ELEMENT B

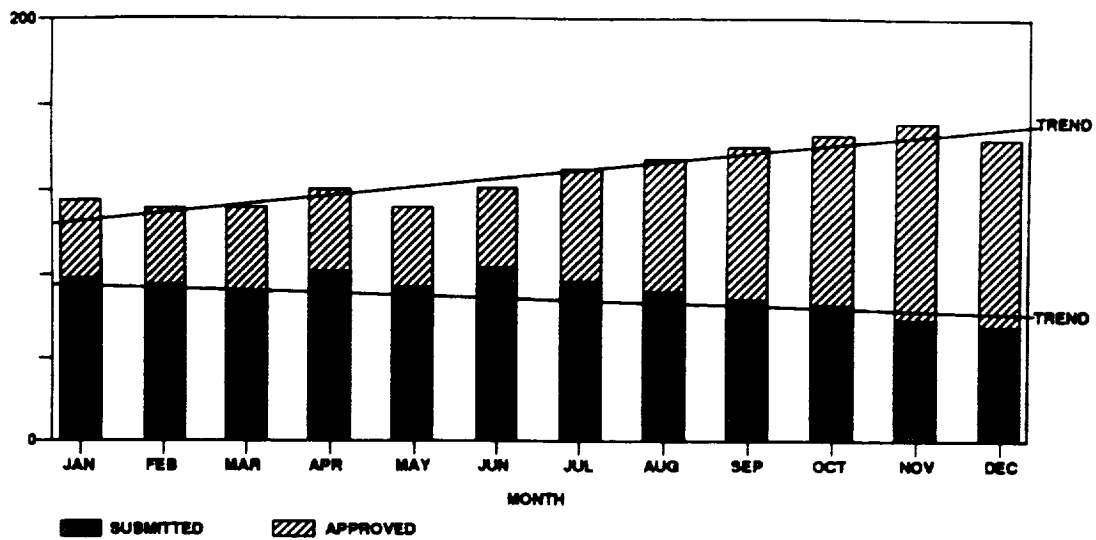


Figure D-6

WAIVERS AND DEVIATIONS PROGRAM ELEMENT A

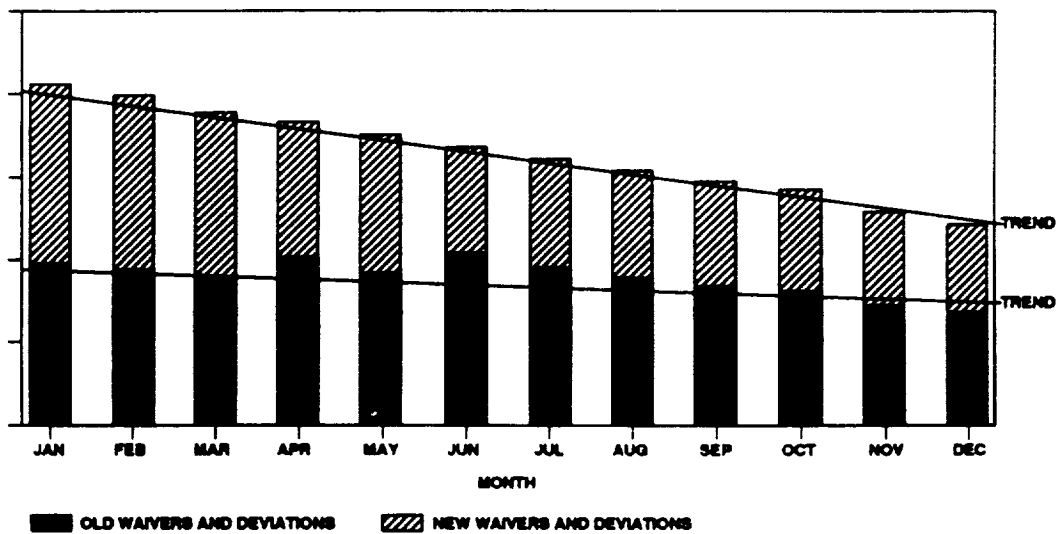


Figure D-7

APPENDIX E
GLOSSARY OF TERMS

The following terms apply to this Handbook:

Abscissa

X coordinates in a rectangular coordinate system.

Cannibalization

The removal of a serviceable (i.e., flight certifiable) item installed in the system element or critical GSE end item to replace an identical unserviceable or missing item in the system when spare availability does not meet demand.

Certification

Documentation stating that personnel, facilities, tools, or test equipment meet prescribed program standards.

Contamination

Any effect arising from the induced environment gaseous, particulate, or radiation background that interferes with or degrades hardware such that refurbishment is required before continued use.

Correction Factors

Mathematical constant or variable factors that remove the effects of known biases, errors, and irrelevant variables from the data under analysis. Normalization is one form of correction.

Corrective Action

Action to eliminate a problem cause that includes one or more of the following dispositions:

- a. Design change
- b. Manufacturing method/procedures/process change
- c. Test procedure change
- d. Facility/test equipment change
- e. Transportation or shipping change
- f. Maintenance procedure change
- g. Training or certification of personnel
- h. Limited time or cycle of component.

Correlation

A measure of the accuracy of a trend model to represent actual data and predict future values.

Critical Item

A system/subsystem with a FMEA criticality of 1, 1S, 2 (with a single point failure), or 1R (if it fails redundancy screens).

Critical Items List (CIL)

An FMEA-derived list (published as FMEA/CIL) containing system items that have a criticality of 1 or 2, and items that are criticality 1R or 2R and fail redundancy screens.

Critical Item Risk Assessment (CIRA)

An evaluation of critical items that combines FMEAs with the associated probabilities of failure.

Critical Software

Software that exercises or protects critical hardware, performs a critical function within specified limits and under specified conditions. (Includes software that performs OMRSD logic sequencing.)

Criticality Categories

A criticality category classification is assigned to every identified failure mode for each item analyzed for all mission phases. Criticality categories are assigned to provide a qualitative measure of the worst case potential consequences resulting from item failure. The criticality categories are defined as follows:

<u>Category</u>	<u>Potential Effect</u>
1	Single failure that results in loss of human life, serious injury to flight or ground personnel, or loss of a major space mission resource (e.g., shuttle, space station, or space telescope).
1R	Failure modes of like or unlike redundant items all of which, if failed, could lead to Criticality Category 1 consequences.
1S	Single failure in a safety or hazard monitoring system that causes the system to fail to detect or operate when needed during the existence of a hazardous condition and lead to Criticality Category 1 consequences.
1SR	Failure modes of like or unlike redundant items in a safety or hazard monitoring system, all of which, if failed, could lead to Criticality Category 1S consequences.
2	Single failure that results in loss of one or more essential mission objectives as defined by the program office without resulting in Criticality Category 1 consequences.
2R	Failure modes of like or unlike redundant items all of which, if failed, could lead to Criticality Category 2 consequences.
3	All other failure modes.

Depot Level Maintenance

Maintenance that is performed by designated maintenance sources. It normally consists of maintenance that requires GSE, facilities, or skills that are not economically available at the intermediate level, (i.e., repairing, overhauling, reclaiming or rebuilding parts, assemblies, subassemblies, components and end items, manufacturing of unavailable parts, and providing technical assistance to the organizational and intermediate levels).

End Item

A system, subsystem, or major item that is capable of performing its intended function unaided except for expendable support, (i.e., fuel, electrical power, gases, connecting hardware, etc.).

Engineering Change Proposal (ECP)

A proposed engineering change to modify, add to, delete, or replace parts in an end item. The term ECP is commonly used to refer to the change after the proposal is approved.

Expedite Action

The need for a spare, repair part, or other supply requirement within a 24-hour time period. This requirement will have been approved by an appropriate level of management.

External Tank (ET)

The expendable element of the Space Shuttle that contains the fuel and oxidizer for the SSMEs. The ET separates from the Orbiter shortly before orbit is achieved, and disintegrates upon reentry into the Earth's atmosphere.

Failure

The inability of a system, subsystem, component, or part to perform its required function within specified limits, under specified conditions, and for a specified duration.

Failure Mode and Effect Analysis (FMEA)

Analysis to determine the possible modes of failure and resulting effects.

Functions

The normal or characteristic actions of an item, sometimes defined in terms of performance capabilities.

Goodness-of-fit

See Correlation.

Institutional Support Facilities

Facilities that support flight operations or research programs/projects, but are the direct responsibility of NASA field activities.

Integrated Problem Assessment System (IPAS)

The problem assessment portion of PCASS where problem report data are stored.

Intermediate Level Maintenance

Maintenance that is performed in direct support of organizational level maintenance and involves disposition, repair, service, modification, calibration, and verification of items removed during organization maintenance.

Launch Commit Criteria (LCC)

Specific performance criteria that must be met to permit launch of a system.

Line Replaceable Unit (LRU)

Any item, the replacement of which constitutes the normally accepted organizational maintenance repair action for a higher indentured item.

Logistics

The branch of engineering concerned with maintaining operational capability throughout the life cycle of a system.

Maintenance

Consists of the actions taken to retain an item in a specified condition by providing systematic inspecting, detecting, and servicing for the prevention and correction of a specified operational condition. This includes fault isolation, item replacement, repair, and verification of serviceability.

Management Information Center (MIC)

A center of information/analysis that is readily available to support management functions.

Mean

The term used to describe a sample population average.

Mean Time to Repair (MTTR)

The average elapsed corrective maintenance time (hours or days) between system, subsystem, or LRU failure and restoration of that system, subsystem, or LRU to an operational state.

Mission 51L

Space Shuttle Mission 51L, the twenty-fifth Space Shuttle mission (tenth flight of the Orbiter Challenger) which experienced catastrophic inflight failure on January 28, 1986.

Nonconformance

A condition of any article of material in which one or more characteristics do not conform to requirements; see Failure.

Nonconforming Article (NCA)

The system/subsystem/part that does not conform to requirements.

Normalization

The process of correcting raw data to remove the effects of nonrelevant variables and allow the data to be compared in "normal" conditions. Compare with correction factors.

Nyquist Sampling Theorem

A mathematical theorem that proves that digital sampling must be performed at twice the highest analog signal frequency/rate to be capable of correctly representing the analog signal.

Nyquist Rate

The minimum digital sampling rate that can accurately represent an analog signal.

Off-Line Maintenance

That maintenance performed at the intermediate or depot levels.

On-Line Maintenance

That maintenance function performed at the organizational level.

Operations and Maintenance Requirements and Specifications Document (OMRSD)

Documents containing preflight maintenance, servicing, inspection, time/age/cycle, and checkout requirements for a flight vehicle or ground-based system.

Orbital Replaceable Unit (ORU)

The lowest level of component or subsystem hardware that can be replaced in orbit.

Orbiter

The reusable space plane element of the Space Shuttle that contains the crew compartment/systems and payload bay.

Ordinate

Y coordinates in a rectangular coordinate system.

Organizational Level Maintenance

Maintenance performed on subsystems and related support equipment in direct support of mission activity. It includes scheduled and unscheduled maintenance actions required to inspect, service, calibrate, replace, repair, and modify in place, and reverify subsystems and associated components.

Parameters

The term applied to population or sample characteristics such as the mean and standard deviation.

Parametric limits

Design performance limits not to be exceeded (upper and/or lower). Certain design parameters may be established with only a single bound.

Pareto Concept

The concept that a relatively large percentage (80-90%) of problems will be caused by a relatively small percentage (10-20%) of related factors.

Pareto Diagram

A rank ordering of problem causes by their contribution, usually in decreasing order.

Performance Trend Analysis

Analysis of data based upon the measurement of specific key performance parameters (e.g., pressure, temperature, and viscosity), which indicate the safe and effective operation of a critical process or item of hardware/software.

Problem

Any nonconformance that fits or is suspected of fitting one of the following categories:

- a. Failure, including conditions that would result in OMRSD waivers
- b. Unsatisfactory condition
- c. Unexplained anomaly
- d. Overstress or potential overstress of hardware
- e. Inflight anomaly
- f. Any nonconformance that has shown by trend analysis to need recurrence control.

Problem Report (PR)

A report of a malfunction, failure, or inadequate performance of a system/subsystem/component.

Problem Reporting and Corrective Action System (PRACA)

A system (usually automated) to record, monitor, and analyze problems and their associated corrective actions.

Problem Trend Analysis

Analysis of data based upon the number of problems occurring in the area under study (e.g., number of problem reports associated with solar panels). Its purpose is to identify the source of key problems and to track whether action taken to resolve the problem is effective.

Program Compliance, Assurance, and Status System (PCASS)

An automated system to compile data from various system and elements to provide program managers with critical information. Common PCASS data include requirements status, problem data, risk decisions, trend analyses, hazards, critical item history, and FMEA/CIL information.

Programmatic Trend Analysis

Analysis of institutional information relating to program schedule and to supporting personnel activities (e.g., employee utilization, worker attrition rates, overtime, and noncompliance with operating procedures). These analyses are used to assess the impact of schedule pressures and major disruption in resource capability or the ability of the work force (or human factor) to respond in a predictably safe and reliable manner.

R-square (R^2)

A quantitative measure of the correlation or goodness-of-fit of a trend model to actual data.

Reliability

The probability that an item will perform its intended function adequately, without failure, for a specific time period under specified conditions.

Reliability Data

All the failure data, inspection findings, and other information derived from the actual service history of each item.

Repair Turnaround Time (RTAT)

The period between the time an item is removed from the system for off-line repair and the time that it is returned in ready-for-installation condition. RTAT includes the time an item is waiting for available shop time, diagnosis, parts, hands-on work, test, and final inspection.

Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA)

The disciplines of assurance engineering that are concerned with the assurance of mission success with minimized risk. SRM&QA commonly is used to refer to those organizations that are collectively concerned with assurance engineering.

Sample Size

The number of items selected from a population that will be used to make inferences about the total population.

Scheduled Maintenance

Preventive-maintenance tasks scheduled to be accomplished at specified intervals.

Shop Replaceable Unit (SRU)

Any item whose replacement constitutes the optimum intermediate or depot level of repair actions for a higher indentured item.

Significant Problem

Any problem that is considered to pose a serious risk to safety or mission accomplishment (schedule and objectives).

Significant Problem Report (SPR)

A means of communicating significant technical problems and anomalous conditions having an impact on safety or mission success upwards through management levels.

Slope

The rate of change in Y per unit change in X for a line plotted in the X-Y coordinate system.

Solid Rocket Booster (SRB)

The element of the Space Shuttle that consists of the two solid rockets attached to the sides of the ET to augment ascent thrust at launch. They are separated soon after lift-off and recovered for reuse.

Solid Rocket Motor (SRM)

The nozzle and control systems of the SRB that provides vectored thrust from the burning of the solid fuel.

Space Shuttle

The manned orbital launching system that is comprised of an Orbiter spacecraft, Space Shuttle Main Engines, External Tank, and Solid Rocket Boosters.

Space Station

A permanent orbital complex comprised of manned, man-tended, and unmanned orbital platforms.

Space Station Freedom

The Space Station manned platform including the ESA Columbus Module and the Japanese Experimental Module.

Space Shuttle Main Engine (SSME)

The reusable liquid fuel engines that provide the main vectored thrust for the Space Shuttle. They are attached to the Orbiter element and are recovered by the reentry and landing of the Orbiter.

Statistical coefficient of determination (R-Square)

The square of the correlation coefficient.

Supportability Trend Analysis

Analysis of the effectiveness of logistics elements in supporting NASA programs/projects. Supportability trend analysis is concerned with the recurrence of logistics problems and the effective control of these problems.

System

A set of components and their connecting links that provide some basic function.

System Automation

The incorporation of sensors and data system capabilities into system and element designs to support automated system status monitoring, trend analysis, fault detection, isolation, and recovery/reconfiguration.

Teardown Inspection/Analysis

Documented results of the test and disassembly of hardware under the direction of the responsible organization to determine if incipient failures may be present.

Technical and Management Information System (TMIS)

An advanced network of compatible hardware and integrated software used to provide systematic management information development and exchange between Space Station Freedom personnel.

Time/Age/Cycle Data

Statistical data that provides information to assure items are removed/replaced at the proper time of the operating life cycle.

Trend Analysis

The analysis and evaluation of an item, system or subsystem, or programmatic element of a program in relation to designed or planned quantitative and qualitative parameters based on actual data collection reports.

Turnaround Time (TAT)

The interval between the time a repairable item is removed from use and the time it is again available in full serviceable condition (see Repair Turnaround Time). Also, vehicle turnaround time, relating to reusable aeronautical or space vehicle processing from wheel stop of one mission to lift-off of the next mission for the same vehicle.

Unsatisfactory Condition Report (UCR)

Rocketdyne Corporation terminology for a problem report.

Variability

A term expressing the dispersion or spread of values about a mean value.

Work Package (WP)

A complement of program activities that is assigned to a selected responsible NASA field installation. It describes the type and scope of the activity to be performed at any level of detail and can include development of hardware, software, interfaces, systems operation, and system utilization operations.

Work Unit Code

An alphanumeric characterizing indentured equipment identification code that uniquely identifies the entire system from the top down to Line or Orbital Replaceable Unit component use level. It functionally identifies the system, subsystem assembly, component, and significant repairable part on which maintenance is to be performed.

This page intentionally left blank.

APPENDIX F **LIST OF ACRONYMS**

A/D	Analog-to-digital
ATP	Acceptance test procedure
CIL	Critical Items List
CIRA	Critical Item Risk Assessment
Code Q	NASA Associate Administrator for the OSMA
Code QS	NASA Headquarters, Safety And Risk Management Division
ECP	Engineering Change Proposal
ET	External Tank
FMEA	Failure Mode Effects Analysis
HA	Hazard Analysis
IDMRDs	Intermediate and Depot Maintenance Requirements Documents
IPAS	Integrated Problem Assessment System
LCC	Launch Commit Criteria
LRU	Line Replaceable Unit
MIC	Management Information Center
MIS	Management information system
MPIS	Management Performance Indicators
MTBF	Mean time between failures
MTBR	Mean time between repairs
MTTR	Mean time to repair
NCA	Nonconforming Article
OMRSD	Operations and Maintenance Requirements and Specifications Document
ORU	Orbital replaceable unit
OSMA	NASA Office of Safety and Mission Assurance

PCASS	Program Compliance Assurance and Status System
POS	Probability of Sufficiency
PR	Problem Report
PR	Procurement request
PRACA	Problem Reporting and Corrective Action
R&D	Research and development
R-Square	Statistical coefficient of determination
RFI	Ready-for-installation
RSRM	Redesigned Solid Rocket Motor
RTAT	Repair turnaround time
SPR	Significant Problem Report
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SRU	Shop Replaceable Unit
SSME	Space Shuttle Main Engine
TAT	Turnaround Time
TMIS	Technical and Management Information System
UCR	Unsatisfactory Condition Report
WP	Work Package

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE October 1993	3. REPORT TYPE AND DATES COVERED Reference Publication
4. TITLE AND SUBTITLE NASA Trend Analysis Procedures		5. FUNDING NUMBERS	
6. AUTHOR(S) NASA Trend Analysis Working Group (TAWG)			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Safety and Risk Management Division Office of Safety and Mission Assurance NASA Headquarters Washington, DC 20546		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546		10. SPONSORING/MONITORING AGENCY NASA RP-1290	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category - 81		12b. DISTRIBUTION CODE	
13. ABSTRACT (maximum 200 words) <p>This publication is primarily intended for use by NASA personnel engaged in managing or implementing trend analysis programs. "Trend analysis" refers to the observation of current activity in the context of the past in order to infer the expected level of future activity. NASA trend analysis has been divided into 5 categories: problem, performance, supportability, programmatic, and reliability. Problem trend analysis uncovers multiple occurrences of historical hardware or software problems or failures in order to focus future corrective action. Performance trend analysis observes changing levels of real-time or historical flight vehicle performance parameters such as temperatures, pressures, and flow rates as compared to specification or "safe" limits. Supportability trend analysis assesses the adequacy of the spaceflight logistics system; example indicators are repair-turn-around time and parts stockage levels. Programmatic trend analysis uses quantitative indicators to evaluate the "health" of NASA programs of all types. Finally, reliability trend analysis attempts to evaluate the growth of system reliability based on a decreasing rate of occurrence of hardware problems over time. Procedures for conducting all five types of trend analysis are provided in this publication, prepared through the joint efforts of the NASA Trend Analysis Working Group.</p>			
14. SUBJECT TERMS trend analysis		15. NUMBER OF PAGES 80	
		16. PRICE CODE A05	
17. SECURITY CLASSIFICATION OF REPORT UNCLASS	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASS	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASS	20. LIMITATION OF ABSTRACT UNLIMITED

Available from NASA Center for AeroSpace Information
800 Elkridge Landing Road
Linthicum Heights, MD 21090
(301) 621-0390

National Aeronautics and
Space Administration
Code J11
Washington, D.C.
20545-0001
Official Business
Penalty for Private Use \$300

BULK RATE
POSTAGE & FEE PAID
NASA
Permit No. G-35

NASA

POSTMASTER

Use Indemnity Insurance
Cover Material in Mail Room
